Fecal Coliform TMDL (Total Maximum Daily Load) Development for Holmans Creek, Virginia

Prepared by:

Science Applications International Corporation
An Employee-Owned Company

11251 Roger Bacon Drive
Reston, Virginia 20190

Prepared for:

Virginia Department of Environmental Quality and
Virginia Department of Conservation and Recreation

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Fecal Coliform Impairment

The Virginia Department of Environmental Quality (VADEQ) listed the Holmans Creek watershed on the Commonwealth's 1998 303(d) TMDL Priority List of Impaired Waters (VADEQ, 1998) because of violations of the fecal coliform bacteria water quality standard. Section 303(d) of the Federal Clean Water Act and the United States Environmental Protection Agency's (USEPA) Water Quality Planning and Management Regulations (40 CFR Part 130), requires states to identify water bodies that are in violation of the water quality standards for any given pollutant. Under this rule, states are also required to develop a Total Maximum Daily Load (TMDL) for the impaired water body. A TMDL determines the maximum amount of pollutant that a water body is capable of receiving while continuing to meet the existing water quality standards. TMDLs provide the framework that allows states to establish water quality controls to reduce sources of pollution with the ultimate goal of water quality restoration and the maintenance of water resources.

Holmans Creek

Holmans Creek is a direct tributary of the North Fork of the Shenandoah River and is located in the North Fork Shenandoah River watershed (VAV-B-45R), which is a portion of the Shenandoah-Potomac River Basin that eventually drains into the Chesapeake Bay. The Holmans Creek watershed is primarily located in Shenandoah County and partially in Rockingham County, approximately 4.5 miles north/northeast of Timberville, Virginia. Land use is dominated by agricultural operations and pastures. The watershed is approximately 12,000 acres in size and contains 12 miles of stream. The Holmans Creek TMDL addresses the stream from its headwaters, which begin east of the George Washington National Forest and flows east, to its confluence with the North Fork of the Shenandoah River about 3.5 miles north of New Market, Virginia.

Sources of Fecal Coliform

There are a number of different fecal coliform sources in Holmans Creek watershed. These sources can be broken into point and nonpoint sources. Point sources are Virginia Pollution

Discharge Elimination System (VPDES) permitted facilities releasing fecal coliforms to Holmans Creek. There are five VPDES permits issued by the Commonwealth of Virginia Department of Environmental Quality. Each of the permits allows for fecal coliform discharges in the Holmans Creek watershed. Four are privately owned permits for single family homes. The fifth permit is for a sewage treatment plant at a local industry. Nonpoint sources are non-permitted facilities or agricultural operations and discharges that enter surface waters in a diffuse manner or intermittently. Nonpoint sources include wildlife, livestock, individual residential sewerage systems, and land application of manure and litter. Beef cattle, poultry and dairy are the major livestock operations in Holmans Creek. Residential sewerage treatment in Holmans Creek consists of direct discharges from straight pipes, privies and failing septic systems. All of these sources contribute to the fecal coliform loadings in Holmans Creek.

Water Quality Modeling

The model selected for Holmans Creek is the US Geologic Survey (USGS) Hydrologic Simulation Program - Fortran (HSPF). HSPF is a set of computer programs that simulate the hydrology of the watershed, nutrient and sediment nonpoint sources loads, and the transport of these loads in rivers and reservoirs. HSPF partitions the watershed into smaller units or sub-watersheds. Watershed specific data on land uses (such as cropland, pasture, forest, and urban), precipitation, meteorological and climate patterns, point and nonpoint sources, and topography are entered into the model for each sub-watershed

The existing flow data at Holmans Creek consisted of a few months of observation (from December 1999 through March 2000) and is inadequate for hydrologic calibration of the HSPF model. Consequently, a “paired watershed” approach was used for model calibration and validation. The closest USGS discharge station with continuous flow is located on Linville Creek, in Broadway, Virginia (USGS Station Number: 01632082), 10 miles from Holmans Creek. This nearby watershed with continuous flow monitoring provides reasonable assurance of similar precipitation and other weather data.

The Linville Creek watershed has been used as a “paired watershed” for several TMDLs in the Shenandoah Valley. A hydrology simulation of the Linville watershed by a calibrated/validated HSPF already existed. The Biological Systems Engineering (BSE)

Department at Virginia Polytechnic and State University provided the Linville Creek watershed HSPF calibrated dataset. The calibrated and validated dataset from Linville Creek was adjusted to reflect the existing total drainage area and land use distribution in Holmans Creek.

Hydrology calibration of the model compares simulated stream flow data to observed data. The model assumptions for hydrology are adjusted within reasonable ranges to achieve a good agreement in the comparison. The period of record selected for the calibration spans from January 1, 1990 to December 31, 1994. This 5-year period was selected because it includes both dry and wet years covering different hydrologic conditions, and are representative of the majority of weather patterns for Holmans Creek. The hydrology validation period was driven by the time period where water quality data were collected in Holmans Creek most of the observed fecal coliform observations were recorded between 1995 and 1999. Allocation model runs were conducted using precipitation data from 1994 to 1998.

Existing Loads and Water Quality

Five point sources currently discharge to Holmans Creek. Nonpoint sources include indirect and direct depositions to surface waters in the basin. Fecal coliform loads associated with the runoff are designated as indirect sources. Sources contributing to the indirect fecal coliform loading in the runoff are wildlife, pets, and livestock. On the other hand, when fecal coliform is directly deposited to the stream it is designated as a direct source. Direct sources can be caused by on-site sewage disposal systems, straight pipes, or by direct deposition in the stream of fecal coliform by wildlife and livestock.

The water quality calibration runs were performed using the existing condition scenario. The intent of this scenario is to reproduce the long-term average fecal coliform fate and transport in the watershed. The simulation period selected for the calibration is from 1994 to 1998. During this period, best management practices (BMPs) were implemented and need to be reflected in the existing condition scenario. As determined by the USGS, 1999 was not considered a representative hydrologic year due to extremely low stream flow values in the Chesapeake Bay region. As a result, 1999 was not included in the simulation period due to the model’s tendency to skew the overall simulation values by producing extremely high, simulated fecal coliform concentrations. These high values can be attributed to the direct source loads (e.g., cattle, septic, wildlife) during extended periods of extreme low stream flow. It indicates a good agreement between observed and simulated values during low and high flow conditions. Comparison to the VADEQ monitoring data to the model output indicated both instantaneous (1,000 counts/100ml) and geometric mean (200 counts/100ml) violations of the water quality standards similar to the observed data.

Margin of Safety

The objective of a TMDL is to allocate allowable loads among the various pollutant sources so that the appropriate control actions can be taken to achieve, with reasonable assurance, water quality standards. Additionally, a margin of safety needs to be incorporated in the allocation scenarios. The margin of safety is included to account for any uncertainty in the TMDL development process and may be incorporated implicitly by using conservative assumptions in the modeling process. The margin of safety may be incorporated explicitly. The state water quality standard for fecal coliform used in the TMDL development is the 30-day geometric mean of 200 counts/100 ml. For the Holmans Creek TMDL, a margin of safety of 5 percent was incorporated explicitly in the TMDL equation by reducing the target fecal coliform concentration from 200 counts/100 ml to 190 counts/100 ml.

Allocation Scenarios

The specific objective of the TMDL plan in Holmans Creek is to determine the required reductions in fecal coliform loadings from point and non-point sources in order to meet state water quality standards in the future. The TMDL development requires that the level of reduction from each pollutant in a watershed be determined in order to meet the applicable water quality standard. The TMDL comprises the sum of individual waste load allocations (WLAs) for point sources and load allocations (LAs) for non-point sources.

TMDL = WLA + LA + MOS

Where:

WLA = waste load allocation (point sources)

LA = load allocation (non-point sources)

MOS = margin of safety
(USEPA, 1999)

The time period selected for the load allocation covers the same period used in the water calibration (January 1994 to December 1998).

Simulation scenarios were then conducted to identify the required reduction from all sources. Based on the results of an array of model runs for sensitivity analyses and allocation scenarios, the TMDL should eliminate fecal coliform loadings from human sources, and significantly reduce direct deposition from cattle, and reduce additional nonpoint source. Wildlife loadings were also included in the allocation plans.

A TMDL for fecal coliform has been developed for Holmans Creek and addresses the following issues.

- The TMDL meets the water quality standard based on the 30-day geometric mean, which explicitly incorporates a margin of safety of 5 percent. After the plan is fully implemented, the 30-day geometric mean will not exceed 190 counts/100 ml.
- The TMDL accounts for all fecal coliform sources (human, agricultural activities, and wildlife).
- A continuous simulation model that applies to high- and low-flow conditions was used. Consequently, both conditions were considered when developing the TMDL.
- Seasonal variations were explicitly included in the modeling approach for this TMDL. The use of a continuous simulation model explicitly incorporates the seasonal variations of rainfall pattern, simulated runoff, and fecal coliform washoff from the land surfaces. In addition, fecal coliform accumulation rates for each land use were developed on a monthly basis. The monthly accumulation rates accounted for the temporal variation in activities within the watershed, including seasonal application of agricultural waste and grazing schedules of livestock.
- The TMDL allocation plan that met the 30-day geometric mean water quality target of 190 counts/100 ml requires a 100% reduction of fecal coliform from failing septic systems, a 100% reduction of direct source loadings from cattle, and a 90% reduction of fecal coliform directly deposited in the stream from wildlife. The summary of fecal coliform TMDL for Holmans Creek is presented in Table ES-1.

Table ES-1. Annual Fecal Coliform Loadings (counts/year) Used for Developing the Fecal Coliform TMDL for Holmans Creek

Parameter	WLA	LA	MOS*	TMDL
Fecal coliform	0.032×10^{12}	$1{,}353 \times 10^{12}$	68×10^{12}	$1{,}421 \times 10^{12}$

*Five percent of the TMDL

Steps to TMDL Implementation

The goal of this TMDL is to establish a path that will lead to an expeditious attainment of water quality standards. The first step in this process was to develop a TMDL that can be achieved with reasonable assurance. The second step is to develop a TMDL implementation plan, and the final step is to implement the TMDL. Section 303(d) of the Clean Water Act and EPA's 303(d) regulation do not provide new implementing mechanisms for TMDLs. However, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act directs VADEQ to develop a plan for the expeditious implementation of TMDLs.

VADEQ plans to incorporate TMDL and TMDL implementation plans as part of the 303(e) Water Quality Management Plans (WQMP). In response to the recent EPA/VADEQ Memorandum of Understanding, VADEQ submitted a Continuous Planning Process to EPA in which Virginia commits to updating the WQMPs, which will be the repository of TMDLs and the implementation plans. Each implementation plan will contain a reasonable assurance section that will detail the availability of funds for implementation of voluntary actions.

Implementation of best management practices (BMPs) in the watershed will continue to occur in phases. Results of monitoring over the last several years have shown reduction in fecal coliform concentrations throughout the watershed. The benefit of phased implementation is that as stream monitoring continues to occur, accurate measurements of progress being achieved will be recorded. This approach provides a measure of quality control, given the uncertainties that exist in the developed TMDL model. The target for the first phase of implementation will be 10% violation of the 1,000 counts/100 ml instantaneous standard.

Modeling runs identified critical periods for water quality attainment, seasonal variation and changes in loads by source. From these runs, allocation scenarios were developed for the Holmans Creek TMDL to be used to develop implementation strategies. Analysis of these runs indicated that low flow critical periods were most influenced by direct deposition of fecal coliform in the stream. Bacteria source tracking performed in the watershed was used to validate model results and identify the most probable sources.

For the Phase I allocation, the model was run for the representative hydrologic period. Using the model developed to represent existing conditions, an allocation scenario was developed that would result in 10% violation of the 1,000 count/100 ml instantaneous standard.

A phased implementation plan is recommended to meet the water quality standards. An iterative approach reducing direct deposition sources and evaluating water quality improvement allows for continued public participation, evaluation of BMP efficiency, and provides opportunity for changes in the implementation strategy to address any uncertainty in the allocation scenario. The modeled scenario for the first stage of implementation requires 100 percent reduction in direct deposition of fecal coliforms introduced to the stream by inadequate domestic treatment and direct deposition from livestock and 25 percent reduction in nonpoint source runoff. Continued monitoring and evaluation of the improvement on the progress already made in Holmans Creek should be incorporated into an implementation plan that evaluates BMP effectiveness and documents the progress toward removing Holmans Creek from the State's 303(d) list.

Public Participation

The development of the Holmans Creek TMDL would not have been possible with out public participation. The Holmans Creek Watershed Committee has been active in organizing stakeholder involvement, assisting citizens to develop an understanding the water quality issues facing the community, and taking steps to address these issues. Coordinating volunteers, initiating water quality monitoring, and seeking out funding to implement BMPs were actions taken by the HCWC.

Three public meetings were held in addition to numerous Holmans Creek Watershed Committee meetings. Each of the meetings was announced in the *Virginia Register* and flyers were distributed in the watershed. Copies of the presentation materials and diagrams outlining the development of the TMDL were available for public distribution The initial public meeting was held in Forestville, Virginia on April 12, 2000, about 25 people attended. Presentations provided information on the state of water quality, an introduction of the TMDL process, and information on how to participate in the development of the TMDL. The second meeting provided more detailed information of the TMDL model, data used to develop the model, and requested comments on model assumptions. The second meeting was held in New Market, Virginia on July 27, 2000, about 25 people attended. The last public meeting, held in New Market Town Hall in New Market on July 31, 2001, presented the final model results and TMDL allocation scenarios, about 21 people attended. Input from these meeting was used to develop the TMDL model and increase the confidence of modeling assumptions and resulting allocation scenarios.

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1. Introduction

1.1 Background

Section 303(d) of the Federal Clean Water Act and the United States Environmental Protection Agency's (USEPA) Water Quality Planning and Management Regulations (40 CFR Part 130), requires states to identify water bodies that are in violation of the water quality standards for any given pollutant. Under this rule, states are also required to develop a Total Maximum Daily Load (TMDL) for the impaired water body. A TMDL determines the maximum amount of pollutant that a water body is capable of receiving while continuing to meet the existing water quality standards. TMDLs provide the framework that allows states to establish water quality controls to reduce sources of pollution with the ultimate goal of water quality restoration and the maintenance of water resources.

The Virginia Department of Environmental Quality (VADEQ) listed the Holmans Creek watershed on the Commonwealth's 1998 303(d) TMDL Priority List of Impaired Waters (VADEQ, 1998). Holmans Creek is a direct tributary of the North Fork of the Shenandoah River and is located in Virginia River Segment VAV-B-45R, which is a portion of the Shenandoah-Potomac River Basin that eventually drains into the Chesapeake Bay.

The Holmans Creek watershed is primarily located in Shenandoah County and partially in Rockingham County, approximately 4.5 miles north/northeast of Timberville, Virginia. It is approximately 12,000 acres in size and contains 11 miles of stream. The Holmans Creek TMDL addresses the stream from its headwaters, which begin east of the George Washington National Forest and flows east, to its confluence with the North Fork of the Shenandoah River about 3.5 miles north of New Market, Virginia. Figure 1-1 shows the location of the Holmans Creek watershed.

1.2 Impaired Water Quality Status

VADEQ determined that Holmans Creek exceeded one of the existing instream fecal coliform water quality standards and identified the source of impairment as being agricultural non-point source runoff. This designation is based on the livestock population and agricultural

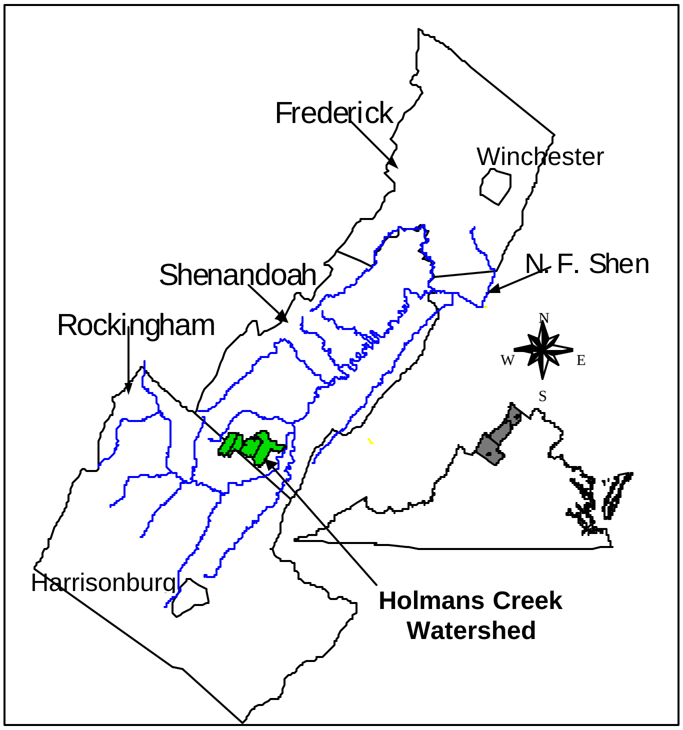

Figure 1-1. Location of Holmans Creek Watershed

activities that occur within the watershed. Additionally, there are five VPDES permitted facilities discharging to Holmans Creek. In a community dominated by cropland and agricultural practices such as the Holmans Creek watershed, fecal contamination can occur in numerous ways. It can be directly deposited to water by animals or faulty septic systems, or it can be applied indirectly deposited to land by animals and/or cropland nutrient application. Fecal coliform bacteria are the resident bacteria in the feces of all warm-blooded animals. Although it is not a pathogenic organism, fecal coliform bacteria is used as an indicator for potential health risks resulting from pathogenic organisms that are also known to reside in feces. A direct correlation can be made between high levels of fecal coliform and high levels of pathogenic organisms.

Holmans Creek watershed has been given a TMDL status of "high priority" resulting from the Virginia Water Quality Assessment for 1996 and Non-Point Source Watershed Assessment Report which designates a "high priority" rating for each of the following parameters: Agricultural Erosion Load (AGER), Agricultural Land Nutrient Load (AGLL), Animal Nutrient Load (AGAL), Total Agricultural NPS Pollution (AGTOT), and Hydrologic NPS RANK (VADEQ, 1996).

1.3 Water Quality Standards

The current VADEQ standards for fecal coliform bacteria contain two criteria, as listed in code 9 VAC-25-260-170. The first criterion, commonly referred to as the "geometric mean standard", states that the fecal coliform bacteria count shall not exceed a geometric mean of 200-counts/100ml of water for two or more samples taken over a 30-day period. The second criterion, or "instantaneous standard", states that the fecal coliform count shall never exceed 1000-counts/100ml of water for any given sampling event. The 303(d) list guidelines require a water to be listed as impaired only if more than 10% of the samples violate the instantaneous standard. In effect, the EPA assessment guidelines accept a 10% exceedance of the instantaneous criterion to allow for inaccuracies during data collection. (VADEQ, 2000). A zero violation standard is applied to the geometric mean criterion. The geometric mean criterion is intended for data sets that include multiple sampling events within a 30-day period. The instantaneous, and most commonly used criterion, applies when fewer than two samples are taken in a 30-day period. The fecal coliform instream water quality data used in the development of the Holmans Creek TMDL consists of monthly VADEQ samples, as well as samples taken by the Holmans Creek Watershed Committee, Virginia Save Our Streams, and the James Madison University Biology Department, which occurred multiple times within a 30-day period.

1.4 Goal and Objectives

The goal of developing the Holmans Creek TMDL is to identify the sources of fecal coliform contamination and to incorporate practices that will reduce fecal coliform loads and allow Holmans Creek to meet Virginia state water quality standards. The following objectives must be completed in order to achieve this goal:

- ***Objective 1*****—**Assess the water quality and identify the potential sources of fecal coliform
- ***Objective 2*****—**Quantify current fecal coliform loads and estimate the magnitude of each source
- ***Objective 3*****—**Model and predict the current fecal coliform loads being deposited from each source
- ***Objective 4*****—**Develop allocation scenarios that will reduce fecal coliform loads
- ***Objective 5*****—**Determine the most feasible reduction plan that can realistically be implemented and incorporate it into the TMDL.

2. Watershed Characterization

2.1 Climate

The climate of the Holmans Creek watershed is a factor in the deposition of fecal coliforms to the waters of Holmans Creek due to the characteristics of the sources and watershed. The source of impairment in this watershed is agricultural non-point source runoff. Non-point source runoff results from rainfall washing pollutants of land surfaces into streams. Extensive precipitation leads to increased runoff of surface water containing fecal coliform from animal feces. Thus, it is necessary to characterize the climate of the watershed to better understand seasonal variations in the levels of fecal coliform concentration. Climatic data from 1991-1999 was obtained from observations from the two weather stations identified in Figure 2-1. The primary data was from the National Weather Service's (NWS) cooperative partner Eddie Coffman in Timberville, Virginia, which is located approximately 3.5 miles south/southwest of the watershed. Supplemental data was developed from the Star Tannery Weather Station in Gravel Springs located in Frederick County, Virginia. The location of these weather stations is displayed in Figure 2-1. The average monthly precipitation and average monthly temperature (high and low) for the period of water quality sampling (December 1991 through December 1999) is displayed in Figures 2-2 and 2-3, respectively.

2.2 Land Use

The Holmans Creek watershed was divided into four sub-watersheds that are identified as (HC-1 through HC-4). Hydrology, surface water flows and spatial considerations such as the location of water quality monitoring stations, and topographical features (elevation) were all factors in the determination of sub-watershed boundaries. Figure 2-4 illustrates this sub-watershed division and sampling station locations.

Another determining factor for source of fecal coliform deposition is land use. Data obtained from the Virginia Department of Conservation and Recreation (VADCR) and the HCWC were used in conjunction with digital ortho quarter quadrangle images to determine the land uses present in the watershed. The 30 land use categories were consolidated into eight categories based on similar characteristics and topographical features to simplify modeling. For

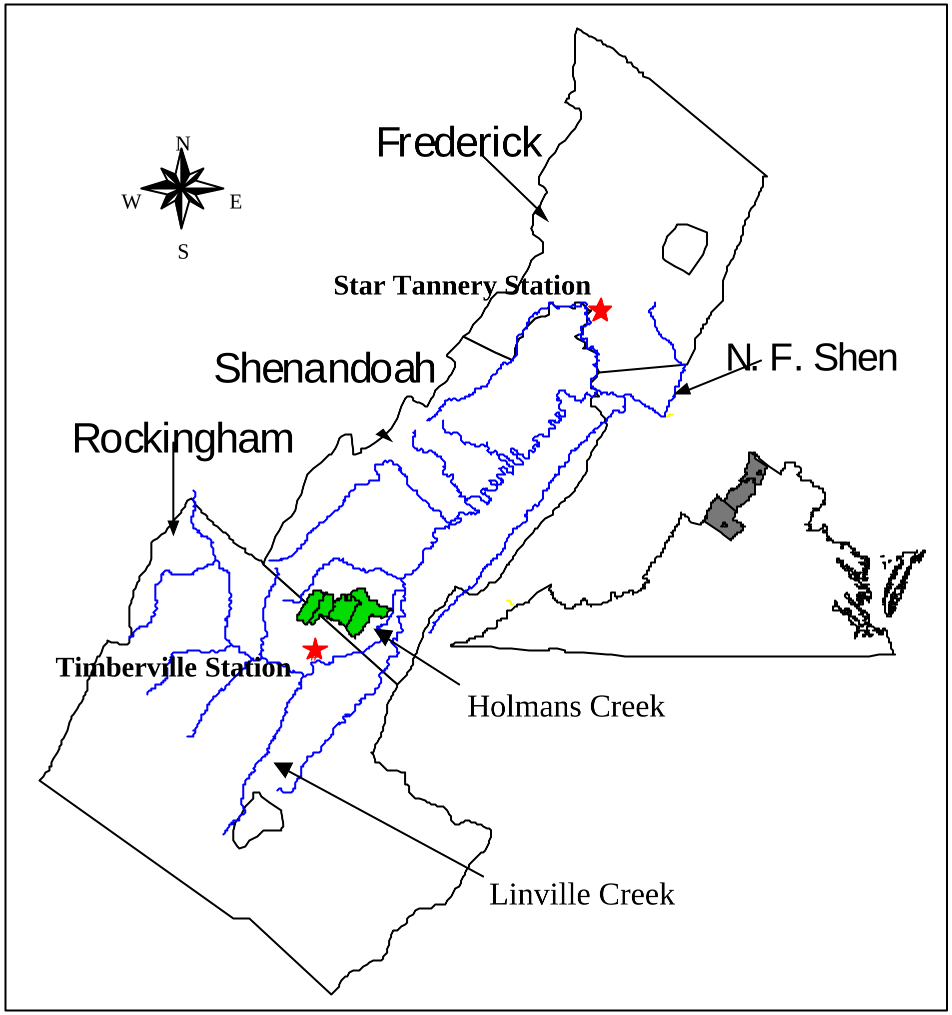

Figure 2-1. Weather Station Locations

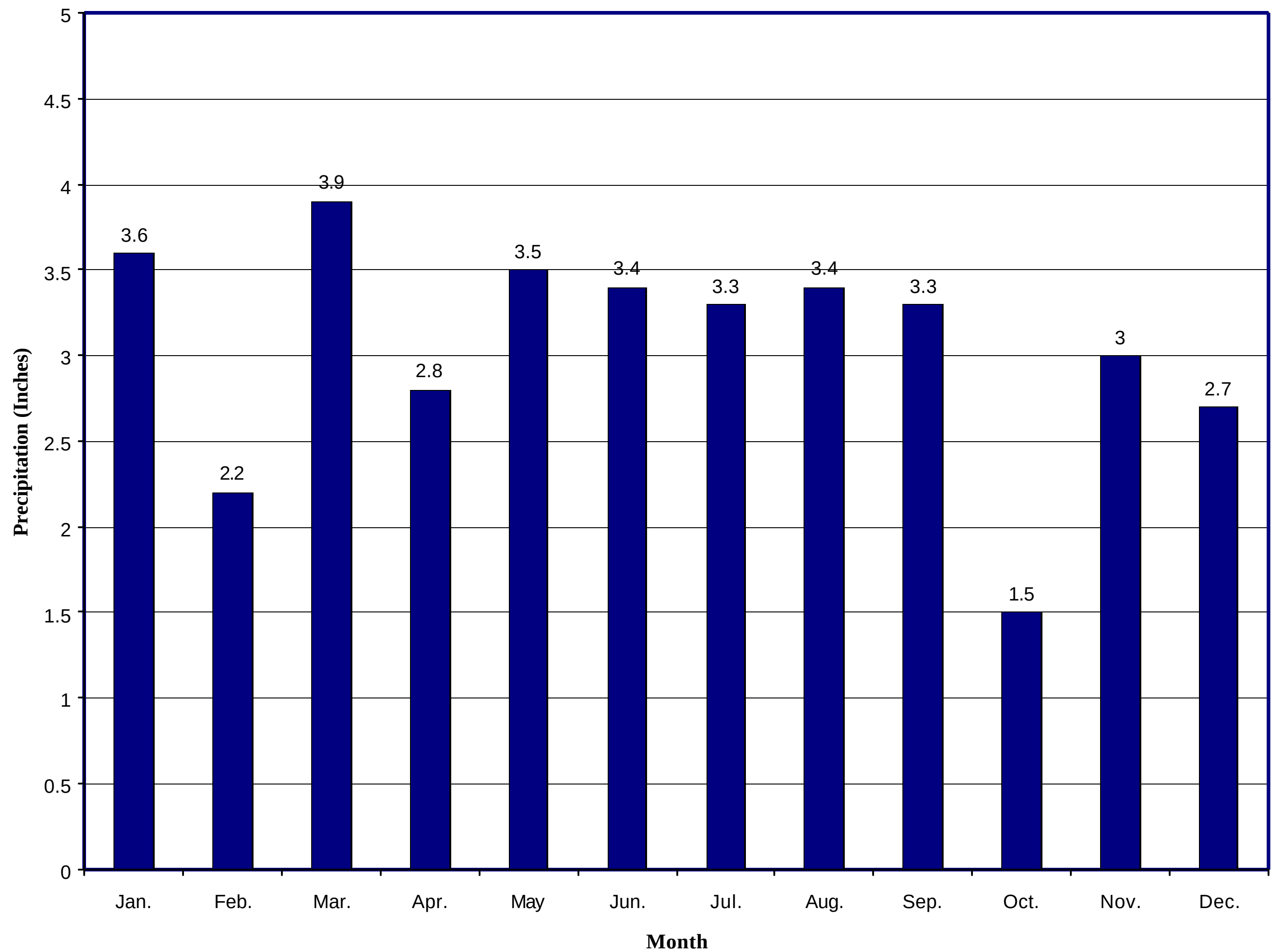

Figure 2-2. Average Monthly Precipitation Values for December 1991 Through December 1999

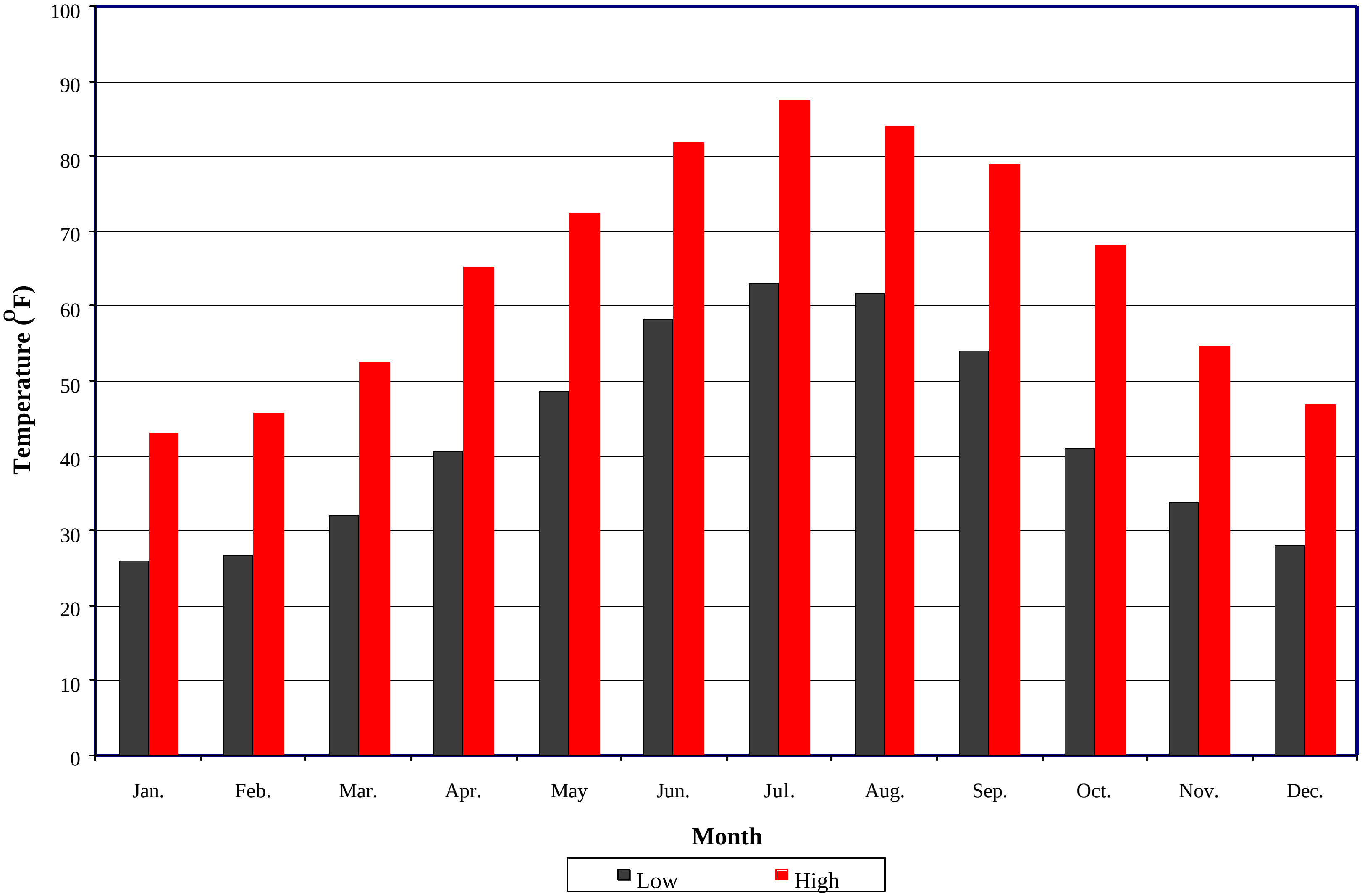

Figure 2-3. Average Monthly Temperatures for December 1991 Through December 1999

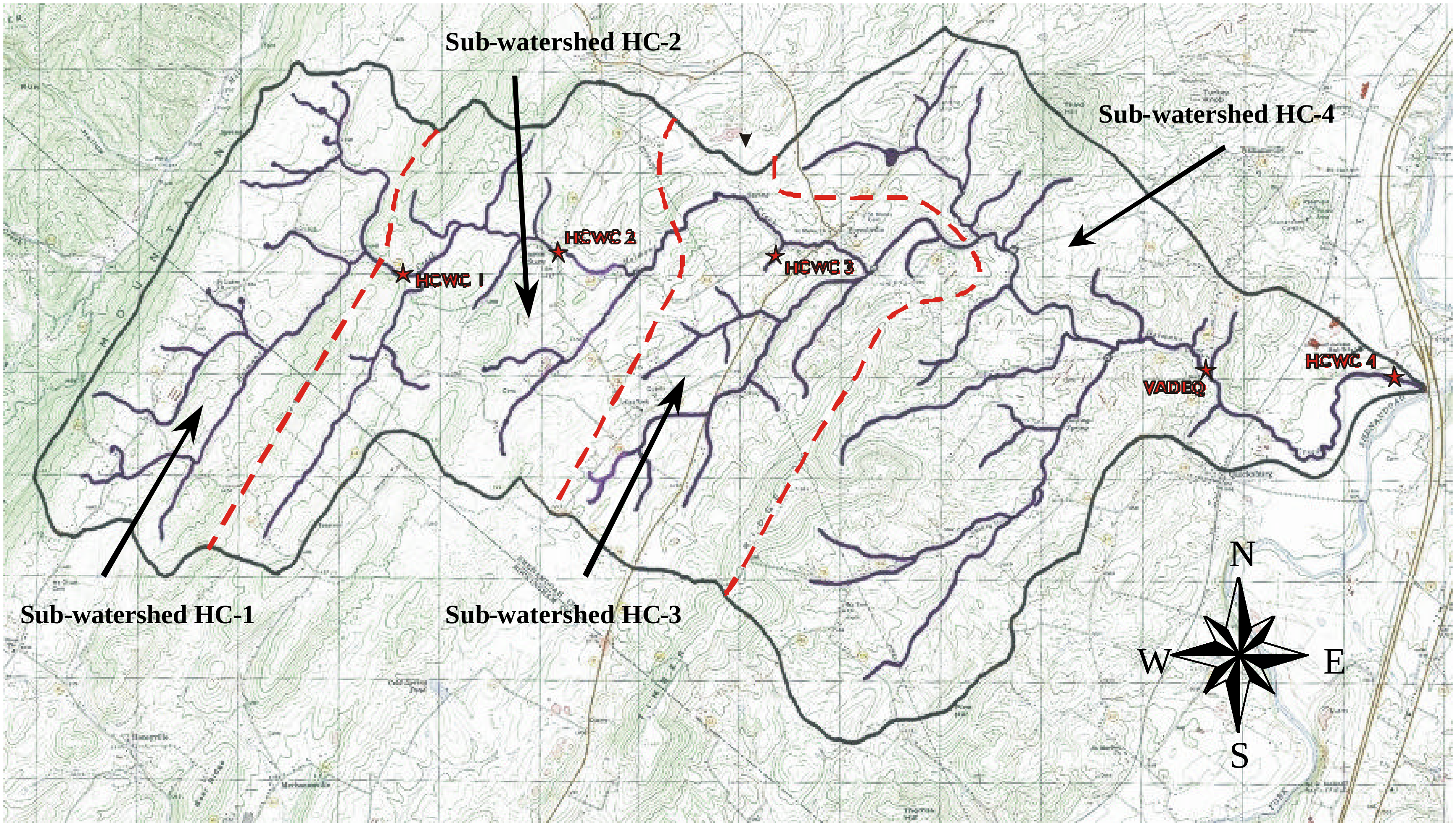

Figure 2-4. Sub-Watershed Division Within the Holmans Creek Watershed

example, commercial services, residential housing, transportation, and mixed urban build up in the watershed were all very similar. These classifications were grouped together based on impervious surfaces to simplify the modeling assumption and TMDL development. The final land use classifications include: cropland, forest, farmstead, mixed urban, orchard, improved pasture/hay, unimproved pasture, and water. Table 2-1 shows the land use conversions while land use distribution is displayed in Table 2-2. Specific land use locations are represented in Figure 2-5.

2.3 Water Quality Data

Holmans Creek water quality data used for the development of this TMDL was compiled from the following sources:

- Virginia Department of Environmental Quality (VADEQ)
- Holmans Creek Watershed Committee (HCWC)
- James Madison University Biology Department (JMU)
- Virginia Save Our Streams (SOS).

Data obtained by HCWC, JMU and SOS was collected at four stations in order to characterize water quality that was representative of the entire watershed. The data collection from these three organizations was arranged by the HCWC, thus these stations are referred to as HCWC Station 1 through HCWC Station 4 throughout the rest of this section. In addition to these four stations the VADEQ collected instream water quality samples from its own monitoring station. This station is referred to as VADEQ Station. Table 2-3 provides a summary of the five water quality monitoring stations used in the development of this TMDL. Figure 2-4 provides the location of each of the five water quality monitoring stations.

2.3.1 Station Analysis

VADEQ established a monitoring station in the watershed as a means of determining the overall quality status of Holmans Creek. Instream water quality monitoring of Holmans Creek began in December of 1991. Presently data is available through January of 2001. Samples were taken approximately monthly and analyzed for fecal coliform concentrations. Comparative analysis of the existing water quality versus the relevant standards resulted in Holmans Creek being listed on

Table 2-1. New Land Use Classifications

Original Classification	New Classification
Barren	Forest
Cattle Operations	Farmstead
Commercial & Services	Mixed Urban
Crop Land	Cropland
Farmstead	Farmstead
Forested	Forest
Grazed Woodland	Unimproved Pasture
Improved Pasture / Permanent Hay	Improved Pasture/Hay
Low Density Residential	Mixed Urban
Mixed Urban Or Built-up Land	Mixed Urban
Orchards	Orchard
Poultry Operations	Farmstead
Transportation	Mixed Urban
Unimproved Pasture	Unimproved Pasture
Water/Wetlands	Water
Wooded Residential	Mixed Urban

Acreage for improved pasture and hay assumed to be equal for the Improved Pasture/Hay land use (Bankson, 2000).

Table 2-2. Land Use Classification by Sub-watershed in Acres

New Classification	HC-1	HC-2	HC-3	HC-4	Total
Cropland	136.47	83.89	344.86	664.04	1229.25
Farmstead	122.41	49.65	89.15	104.31	365.52
Forest	753.58	448.22	813.78	1475.07	3490.64
Mixed Urban	0	19.10	33.88	176.03	229.02
Orchard	45.11	517.30	119.06	144.10	825.57
Improved Pasture/Hay	1155.29	449.24	1221.77	2348.21	5174.50
Unimproved Pasture	81.03	178.42	268.45	101.69	629.59
Water	6.09	24.78	3.63	11.65	46.14
Total	**2299.97**	**1770.60**	**2894.59**	**5025.10**	**11990.24**

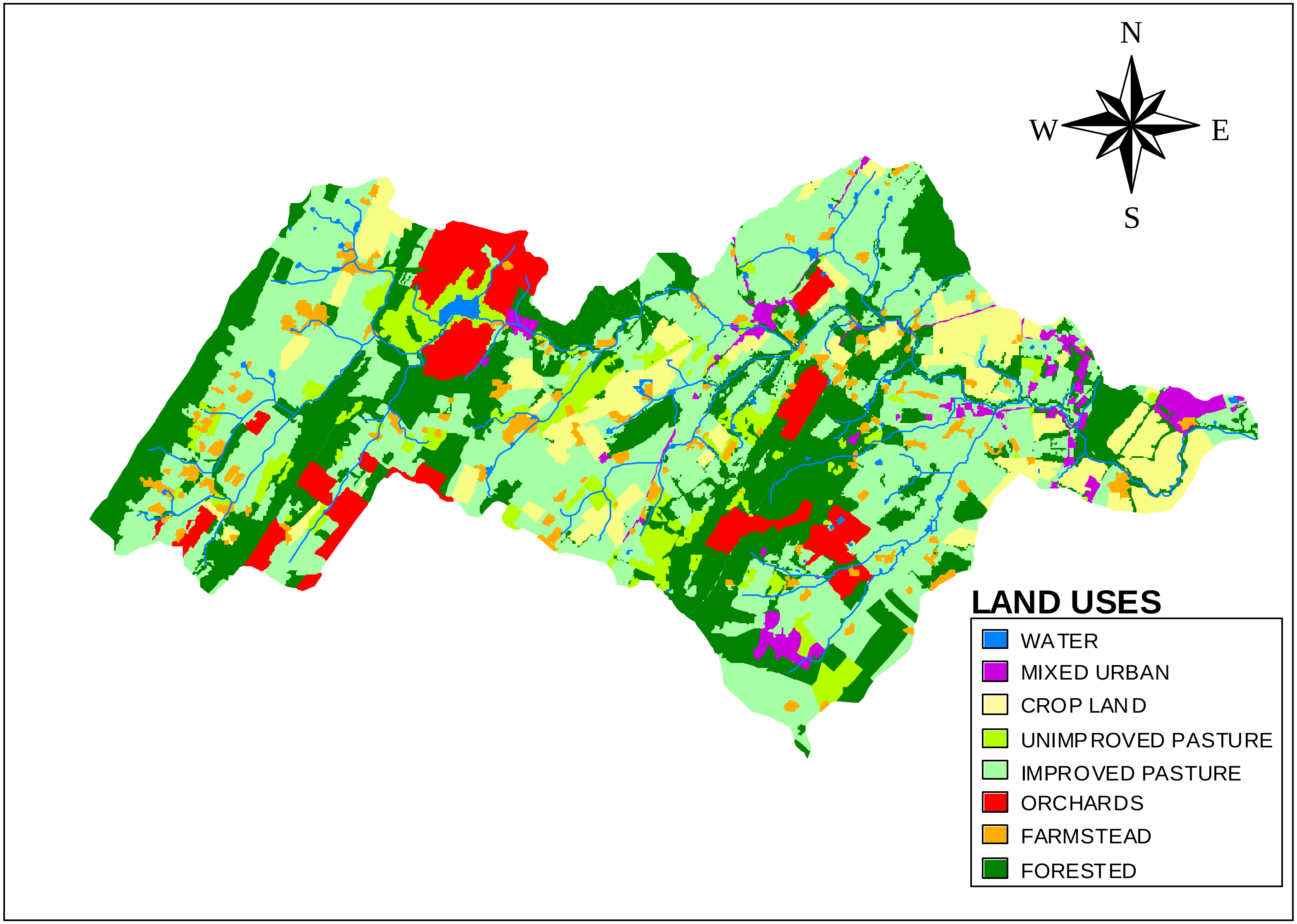

Figure 2-5. Land Use Categories Within the Holmans Creel Watershed

Table 2-3. Sampling stations in the Holmans Creek Watershed

Site/Station	Location	Frequency	Period of Sampling
HCWC Station 1	N. Mountain Rd., 2 mi. east on Rt. 613	Bi-weekly	12/94 - 12/99
HCWC Station 2	Bridge at Rt. 728 and Rt. 614, (Moores Store)	Bi-weekly	12/94 - 12/99
HCWC Station 3	Bridge 2 mi. east of Rt. 42 at Rt. 767 (Forestville)	Bi-weekly	12/94 - 12/99
HCWC Station 4	I81 at Rt. 780 (Burch's Farm)	Bi-weekly	12/94 - 12/99
VADEQ Station	Rt. 698 Bridge	Monthly	12/91 - 12/98

the 303(d) list for fecal coliform content. Since fecal coliform levels are the focus of this TMDL, it is the only polluting factor that is analyzed. Figure 2-6 presents temporal fecal coliform concentration data for the VADEQ station within the Holmans Creek watershed.

It should be noted that prior to 1995, the Most Probable Number (MPN) method was used to determine the fecal coliform concentration of a particular water source. This method of analysis is limited by its detection limit, which exists at a maximum of 8,000 fecal coliform/100ml. However, a more accurate method, Membrane Filtration Technique (MFT), was developed and used throughout the remaining of the water quality analysis. MFT has a maximum detection limit of 16,000 fecal coliform/100ml.

Since the samples were taken monthly, the instantaneous standard of 1,000 fecal coliform/100ml is applied. Thirty seven percent (29) of the 79 samples taken from December 1991 through January 2001 were in excess of the instantaneous standard. Two samples (one percent) were equal to the 1,000 fecal coliform/100ml standard. A major portion, 73 percent (21) of the 29 samples in violation were observed prior to November 1996.

Additional instream fecal coliform water quality analysis was performed by HCWC in conjunction with JMU and SOS. Sample collection began in December 1994 and continued through December 1999. Samples were collected at least once a month and often times more than once a month. This fact allows the instantaneous criterion as well as the geometric mean criterion to be applied to these samples. Table 2-4 presents the violation frequencies for each fecal coliform standard criterion as observed at each of the four HCWC water quality monitoring stations as well as the VADEQ station.

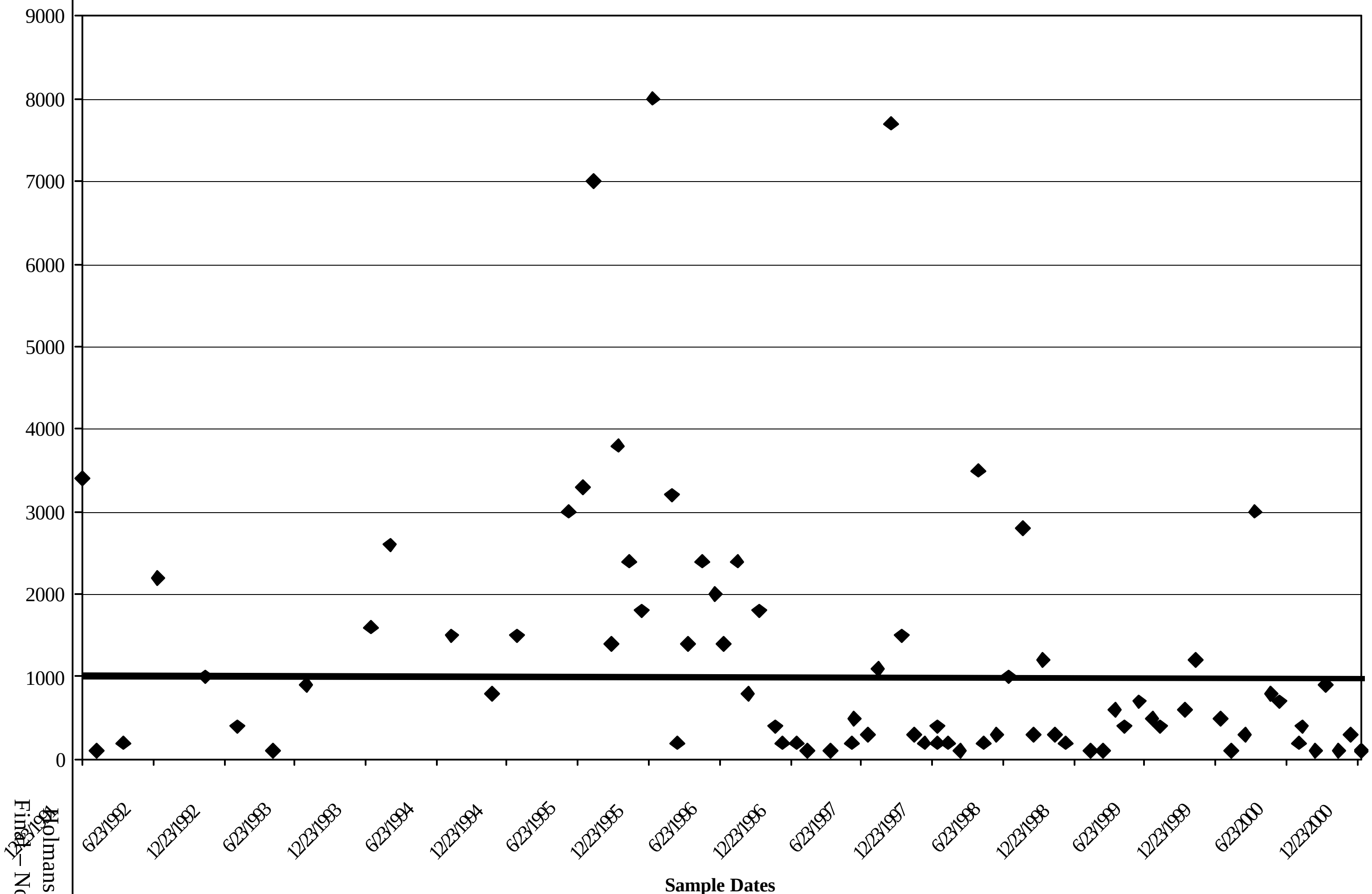

Figure 2-6. Fecal Coliform Concentration Data for the VADEQ Water Quality Sampling Station (December 1991 – January 2001)

Table 2-4. Fecal Coliform Standard Violation Frequency for the HCWC Stations

Site/Station	Frequency of Violations for the 1,000 counts/100 ml Standard (%)*	Frequency of Violations for the 200 counts/100 ml Geometric Mean Standard (%)**
HCWC Station 1	14.3	39.3
HCWC Station 2	9.3	34.5
HCWC Station 3	16.3	62.1
HCWC Station 4	23.3	65.5
VADEQ Station	36.7	95.7
Overall	22.4	60.0

* All available data (171 observations) were used to calculate the frequency of violation for the 1,000 counts/100mL Standard

** Data sets gathered within a 30-day period (115) were used to calculate the frequency of violation for the 200 counts/100mL Geometric Mean Standard.

A comparison of the instantaneous standard violation frequencies for the VADEQ Station versus HCWC Stations 1 through 4 shows significantly higher levels of violation at the VADEQ station. Less than half of the data collection from the HCWC stations (December 1994 through November 1996) occurred during the period of elevated violations for the VADEQ station. A comparison of the post November 1996 VADEQ Station violation frequency (22 percent) and the HCWC station's overall violation frequency (16 percent) are similar. Regardless, four out of the five monitoring stations are in excess of the instantaneous standard more than the impaired classification level of 10 percent. Further analysis shows that the frequency of violation of the geometric mean standard for the HCWC stations is greater than 0 percent standard for each of the four stations. Thus, analysis of each of the five stations verifies the necessity for the impaired watershed classification.

2.3.2 Seasonal Analysis

Seasonal variation for instream fecal coliform concentration was performed for Holmans Creek. Mean monthly fecal coliform concentration values were determined and grouped into the following seasons: December – February (Winter), March – May (Spring), June – August (Summer), and September – November (Fall). Data from VADEQ and HCWC monitoring stations were analyzed separately and compared. Seasonal data is devoid of spatial data, therefore, the data from all four HCWC monitoring stations were combined to produce a single seasonal value. Figure 2-7 and Figure 2-8 present these seasonal mean values for the VADEQ Station and the four HCWC Stations respectively.

Results show that the mean fecal coliform concentrations for the samples collected by the VADEQ are above the instantaneous standard for all four seasons, with the highest mean values occurring during the Summer season. The results for the four HCWC Stations show both the spring and summer seasons as having significantly higher mean fecal coliform concentrations.

The seasonal frequency of violation was evaluated for the VADEQ Station and the four HCWC Stations. The VADEQ Station data from 1991 through 2000 does not provide a sampling frequency sufficient to calculate a geometric mean. The HCWC stations data are applied to both the instantaneous and geometric mean standard. The frequency of violation for each season is presented in Table 2-5.

Analysis of the seasonal violation frequencies of the instantaneous standard shows that all four seasonal frequencies are equal to or above the 10 percent level for both the VADEQ Station and the HCWC stations. The violations occur most frequently in the summer for both the VADEQ Station and the HCWC monitoring stations and values are high for the spring months as well. The elevated levels of fecal coliform are most likely a result of a combination of factors. Livestock confinement rates are much lower during the warmer months resulting in higher fecal coliform concentrations due to cattle directly deposit feces into or near the stream. Land application of animal wastes is much greater in the warmer months, especially during the spring, due to the nature of manure and litter to act as a nutrient to crops. Precipitation rates are higher from March through August, resulting in higher runoff rates in a watershed dominated by agricultural non-point source runoff.

2.3.3 Fecal Typing

Fecal typing involves several relatively new scientific methods to identify the source of fecal pollution in a particular water source. Antibiotic Resistance Analysis (ARA) applies a system of statistical analysis (discriminant analysis) to the antibiotic resistance patterns of fecal streptococci from known pollution sources in order to classify the source of the fecal streptococci

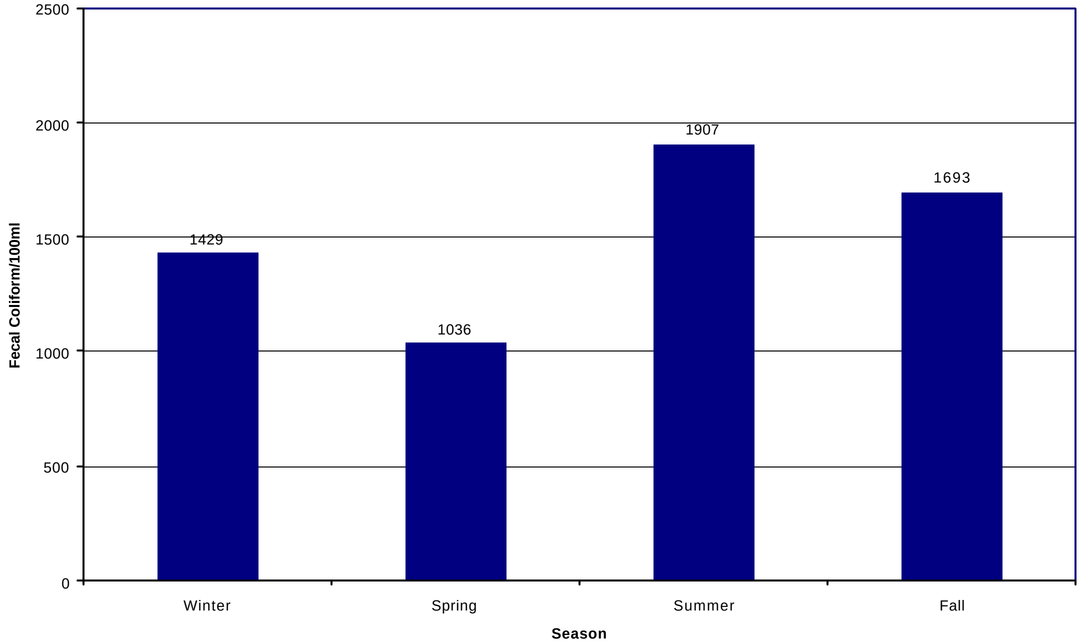

Figure 2-7. Mean Fecal Coliform Concentrations for the VADEQ Water Quality Monitoring Station by Season from 1991-2000

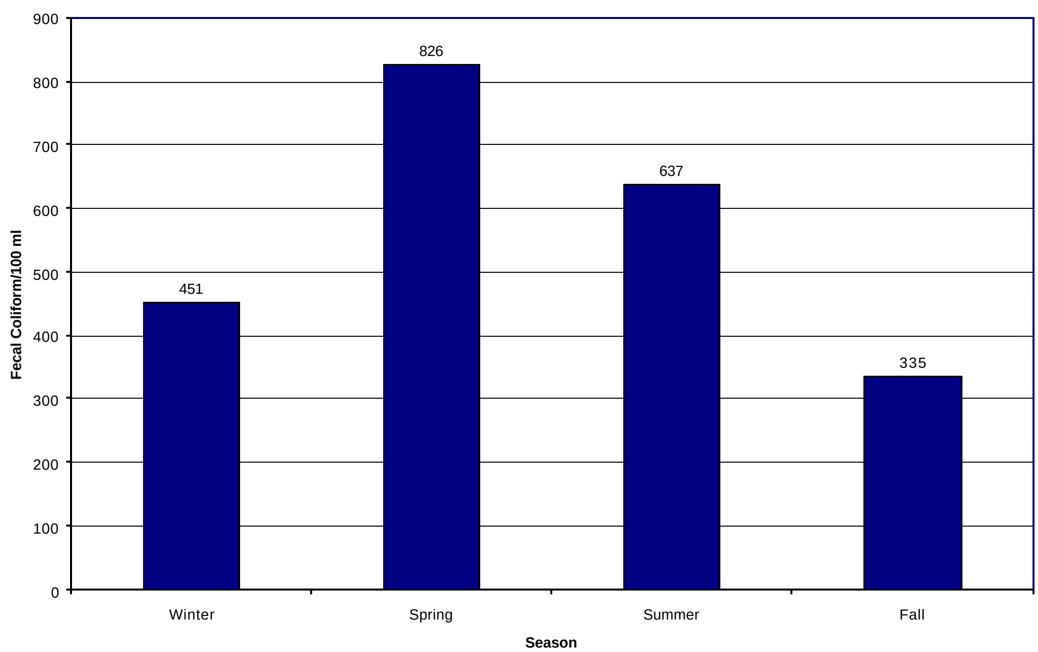

Figure 2-8. Mean Fecal Coliform Concentrations for HCWC Water Quality Monitoring Stations by Season from 1994-1999

Table 2-5. Fecal Coliform Standard Violation Frequency for the VADEQ and HCWC Stations

Season	Frequency of Violations for the 1,000 counts/100 mL Instantaneous Standard* (%)	Frequency of Violations for the 200 counts/100 mL Geometric Mean Standard** (%)
VADEQ Station		
Winter	41.2	N/A
Spring	36.4	N/A
Summer	64.3	N/A
Fall	50.0	N/A
Overall	48.2	N/A
HCWC Stations 1-4		
Winter	13.2	46.2
Spring	18.8	91.7
Summer	21.1	100.0
Fall	10.0	100.0
Overall	15.7	74.2

* All available data (171 HCWC station observations and 56 VADEQ Station observations) were used to calculate the frequency of violation for the 1,000 counts/100mL Standard

** Data sets gathered within a 30-day period (31) were used to calculate the frequency of violation for the 200 counts/100mL Geometric Mean Standard.

found in the polluted water. This system uses the antibiotic resistance patterns to 18 drugs (initially a nine drug library was used) of the bacteria located in the enteric tract of potential polluting sources (i.e. cattle, poultry, human, wild) as a means of differentiating between these sources (Wiggins, 1999).

ARA was applied to the Holmans Creek Watershed by the James Madison University Biology Department as a means to identify the major sources of fecal pollution of this water source (Wiggins, 2001). Samples were taken from seven monitoring stations located throughout the watershed on seven occasions beginning in June, 1999 and continuing through February, 2000. These seven monitoring stations are separated and identified by the sub-watershed. There are no fecal typing stations located in HC-1. Sub-watersheds HC-2 and HC-3 each have two fecal typing stations located within them and HC-4 has three stations.

Based on the known resistance patterns of each potential polluting source, the ARA method determines the approximate percentage of fecal coliform from each individual source per sample.

Table 2-6 presents the overall fecal coliform source classification in Holmans Creek, taken over five sampling dates, broken down by sub-watershed.

Analysis of the fecal coliform data suggests that the primary source of fecal pollution is human. Human sources contribute slightly less than half of the total fecal coliform deposited into the waters of Holmans Creek. Wildlife and cattle sources each contribute approximately one quarter of the total fecal coliform loads in the watershed. Poultry was determined to be a minor contributor to fecal coliform pollution in Holmans Creek, contributing one tenth of the total fecal load.

Table 2-6. Classification of Unknown Fecal Isolates by Sub-watershed

Sub-watershed	Cattle %	Human %	Poultry %	Wild%
HC-1	N/A	N/A	N/A	N/A
HC-2	28.6	**39.2**	7.9	24.4
HC-3	16.8	**44.6**	10.0	28.9
HC-4	22.5	**41.7**	12.5	23.3
Overall	22.6	**41.8**	10.1	25.5

Bolded values indicate that source as the highest percentage of classification for a particular station (Wiggins, 2001)

3. Source Assessment

There are a number of different fecal coliform sources in Holmans Creek watershed. These sources can be broken into point and nonpoint sources. This chapter will discuss each source of fecal coliform in Holmans Creek Watershed and the data used to estimate the quantity of fecal coliform generated by each source.

Data for fecal coliform sources were pulled from a variety of sources. These included existing Virginia Pollution Discharge Elimination System (VPDES) permits; land use data; nutrient management plans; literature values on the fecal coliform production rates of different animals; US Census Bureau population statistics; US Geological Survey (USGS) maps and satellite photography; animal density data; and information on farming practices provided by nutrient management specialists, farmers, and farming associations. Further detail on sources of data and assumptions used are included throughout the following section.

3.1 Point Sources

Point sources are discharges to water bodies that come from a single specific location. An example is a wastewater treatment plant for an industry or sewage system. There are five VPDES permits issued by the Commonwealth of Virginia Department of Environmental Quality. Each of the permits allows for fecal coliform discharges in the Holmans Creek watershed. Four are privately owned permits for single family homes. The fifth permit is for a sewage treatment plant at a local industry. Table 3.1 identifies the permitted facility and homes, the discharge volumes, fecal coliform limits, and the approximate location of the discharge outfall in the watershed.

Privately owned VPDES permits are issued under the General VPDES Permit for Domestic Sewage Discharges of Less than or equal to 1,000 Gallons per Day (VAG40). These permits are issued to individuals to treat domestic wastewater and release the treated water to Holmans Creek due to inadequate soils, proximity of the water table, and or rock ledges that prevent construction and performance of standard septic systems. The four permits issued in Holmans Creek are located in subwatersheds HC1 and HC2. The discharge limitations allow a maximum instantaneous fecal coliform concentration of 200 counts/100 ml.

Table 3.1. VPDES Permitted Discharges to Holmans Creek

Permit VPDES	Receiving Stream	Category	Sub-watershed / Approximate Location	Discharge Volume (gpd)	Fecal Coliform Limit (counts/100ml)	Annual Loading (counts/year)
Commercial						
VA0088285	Holmans Creek	STP[1,2]	HC2 Bowman Ag. Ent.	7,500	200	20.7E+9
Residential						
VAG401541	Holmans Creek, U.T.	SFH[3]	HC1 SR 613	1,000	200	2.76E+9
VAG401958	Holmans Creek, U.T.	SFH	HC1 SR 613	1,000	200	2.76E+9
VAG401349	Holmans Creek	SFH	HC2 Forestville	1,000	200	2.76E+9
VAG401809	Holmans Creek	SFH	HC1 Moores Store	1,000	200	2.76E+9
Total						31.74E+9

1. Sewage Treatment Plant
2. The fecal coliform limit is based on the geometric mean
3.Single Family Home

The Commonwealth of Virginia, Department of Environmental Quality has issued a VPDES permit to Bowman Agricultural Enterprises, LLC for a future discharge. When the planned sewage treatment plant becomes operational, it will be subject to a monthly average geometric mean fecal coliform limit of 200 counts/100 ml. The design flow for this facility is 0.0075 MGD. Because this facility is not yet operational, it will be assumed that the discharge of fecal coliform is equal to the permit limit. Discharge from this facility will be evaluated in development of allocation scenarios. This source, shown in Figure 3-1, will discharge to sub-watershed HC-2.

3.2 Nonpoint Sources

Nonpoint sources include septic systems, wildlife, pets, and livestock. Each are discussed separately in the following sections. Table 3-2 provides a comparison of the fecal coliform loading associated with each of the sources.

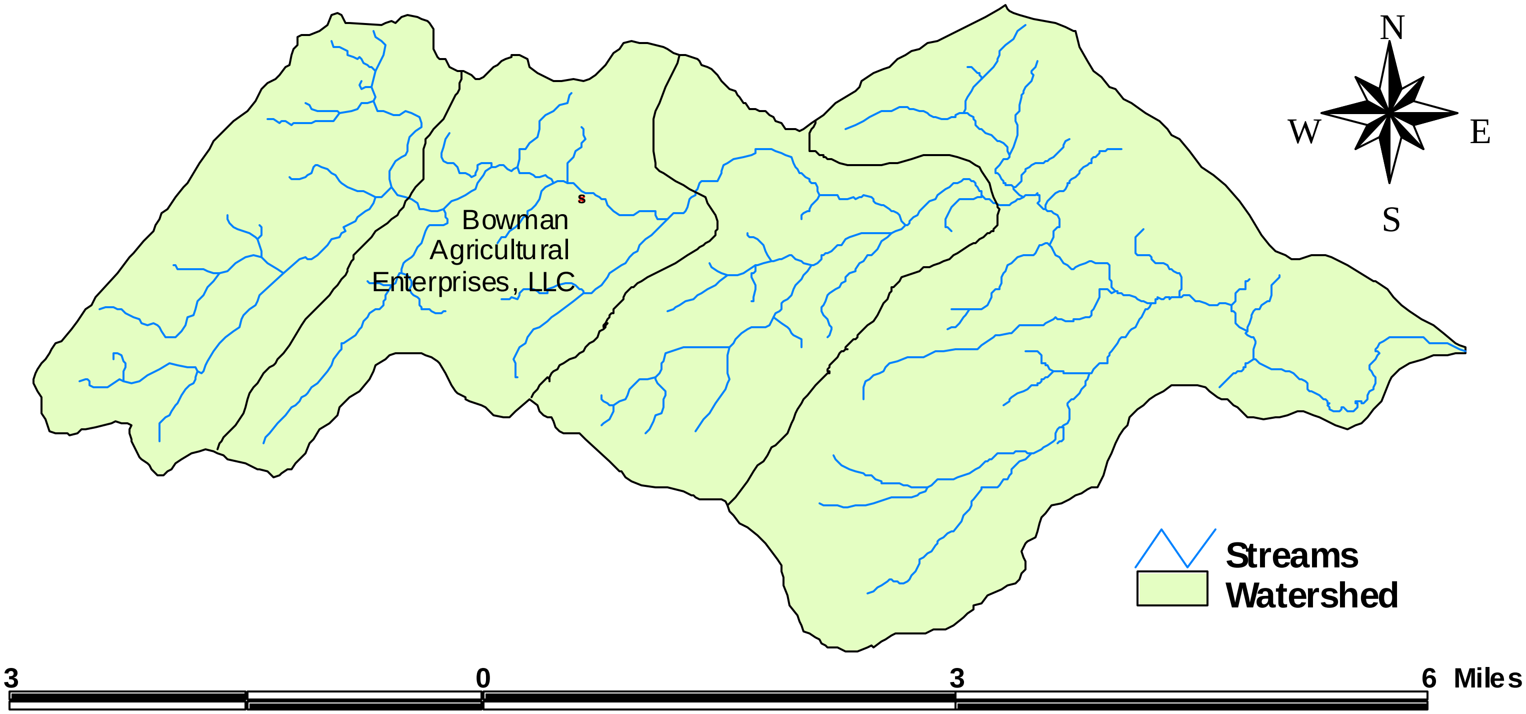

Figure 3-1. Location of Planned Sewage Treatment Facility in Holmans Creek

Table 3-2. Fecal Coliform Loads per Source

Source	Load (cfu/day)
Human[1]	2.64E+08
Deer[2]	2.55E+09
Goose[2]	7.20E+04
Racoon[2]	2.30E+09
Beaver[2]	2.00E+05
Muskrat[2]	1.90E+08
Dog[1]	4.50E+08
Chicken[3]	2.40E+08
Cow[3]	5.40E+09
Turkey[3]	1.30E+06

[1] Geldreich, 1978
[2] MapTech, 2000a
[3] Metcalf and Eddy, 1979

3.2.1 Residential Sewage Treatment

The contribution of fecal coliform to Holmans Creek is based on the number of persons in the watershed using household wastewater systems that do not remove fecal coliform. An investigation of the watershed, its major tributaries, and septic systems was conducted by the Holmans Creek Watershed Committee (HCWC) from 1995 through 1999. This investigation showed a range of human waste disposal practices in use in the watershed. The vast majority of the households use septic systems, as there are no wastewater treatment plants that accept sewage from the watershed. There are homes that depend on straight pipe, straight pipe equivalents, pit privies, and cesspools. These systems provide no treatment wastewater.

The investigation was conducted under the Farm*A*Syst Program which addresses potential on-site risks to well water quality and septic systems where evaluated. As a result of this survey HCWC estimated that 30 percent of the homes in the watershed had sewage systems that were failing or are inadequate to provide proper treatment (Bankson, personal communication, August 20, 1999).

Additionally, Holmans Creek watershed is located in a karst area. Karst areas refer to topography that is underlain by limestone. Over time, this limestone is dissolved by water and carbon dioxide causing cracks, fissures, and joints in the limestone. Eventually, as the limestone continues to dissolve, sinkholes, sinking streams, and caverns may be formed. In karst areas, water can flow rapidly through the limestone and into the groundwater and subsurface flow without being filtered through soil and vegetation. This increases the pollution potential of inefficient and failing septic systems. Effluent rising to the surface is transported to receiving waters in the surface runoff . Septic tanks that are located improperly can release fecal coliform and other pollutants.

A similar study performed for the Dry River TMDL estimated that 24 percent of the septic systems in that watershed were failing (BSE, 2000). This study estimated that homes have 20-40 percent septic failure rate when older than 17 years. Additionally, houses older than 17 years and within 150 feet of a tributary between 10-2 percent were assumed to use straight pipes.

Based on the data developed in the Holmans Creek study and supported in similar studies, an estimated 30 percent of the houses in the watershed have straight pipes, failing septic systems, or antiquated wastewater treatment. Wastewater from these failing or inadequate systems is transported either directly to Holmans Creek or one of its tributaries. This value provides a conservative estimate of the failed systems, systems that provide no treatment, and accounts for the increased pollution potential of the underlying geology. The reference to failing septic systems in the TMDL accounts for all of these systems.

In order to determine the number of houses in the watershed, United States Geologic Survey (USGS) topographic maps were used to determine the number of houses in each sub-watershed. The 1983 and 1994 versions of the USGS 7.5 minute quadrangle maps were used to determine the number of houses for each of these years. These household numbers were then extrapolated, using a linear regression, to the year 2000. Table 3-3 depicts the number of households in the Holmans Creek watershed for each of the four model-segments in the watershed.

The 1990 US Census data were used to determine population living in the Holmans Creek watershed. Holmans Creek watershed is located in two counties: Rockingham and Shenandoah. The census data show an average of 2.54 people per household in Shenandoah County and an average of 2.75 people per household in Rockingham County. As the majority of households were in Shenandoah County, an average household density of 2.54 people per household was used to estimate the population in each sub-watershed.

Table 3-3. Households by Model Segment

Sub-watershed	Households 1983	Households 1994	Households Est. 2000
HC-1	45	82	102
HC-2	28	63	82
HC-3	67	141	181
HC-4	90	183	234
Total	**230**	**469**	**599**

(Source: USGS 7.5 minute quadrangle maps)

A concentration of 10^5 counts/100ml is used to estimate the fecal coliform load from failing septic systems. This value is a lower-end concentration of fecal coliforms for human wastes in septic systems, and is used to account for fecal coliform die-off and transport to the stream (Metcalf and Eddy, 1979). A value of 70 gal/day/person is used to estimate the load.

Thus, it is estimated that human wastewater contains 2.64×10^8 cfu/day of fecal coliform. Using this information, the number of houses, the number of people per house, and the direct annual fecal coliform load to Holmans Creek was estimated. Table 3-4 provides a summary of households and people who are using wastewater systems that do not provide appropriate treatment.

Table 3-4. Septic Systems contributing to the Direct Fecal Coliform Load in 2000

Sub-watershed	Total Septic Systems	Failing Septic Systems [1]	People on Failing Septic
HC-1	102	31	78
HC-2	82	25	62
HC-3	181	54	138
HC-4	234	70	178
Total	**599**	**180**	**456**

(Source: USGS 7.5 minute quadrangle maps)

1. Thirty percent failure was used to estimate the number of households with failed or inadequate septic systems, straight pipes, and cesspools (Bankson, personal communication, 2000).

3.2.2 Wildlife

There are a variety of wildlife species in the Holmans Creek watershed that contribute to the fecal coliform load. This section describes how estimates were developed for:

- Deer
- Geese

- Raccoons
- Beavers
- Muskrats.

Based on information provided by Virginia Department of Game and Inland Fisheries (VA DGIF), the deer population in Shenandoah County can be estimated at 45-50 deer/square mile (Kocha, personal communication, August 1, 2000). The majority of Holmans Creek watershed lies in Shenandoah County; therefore, this density value was applied for land uses that would support deer populations for the entire watershed. For this analysis, a population factor of 0.74 deer/acre was applied to all forest, pasture, and cropland. It was assumed that two percent of the fecal matter was deposited directly into the stream, and that the remaining 98 percent were evenly distributed between forest, cropland, improved pasture, and unimproved pasture.

Based on year-round observations made by the Holmans Creek Watershed Coordinator, Rod Bankson, it is estimated that 250 geese reside permanently in the watershed (Bankson, personal communication, May 1, 2000). These resident geese were distributed across the sub-watersheds based on the percentage of total geese habitat (e.g., water, wetland, and pastureland) located in each sub-watershed. It was assumed that 50 percent of the fecal matter was deposited directly into the stream and that the remaining 50 percent was deposited on land (MapTech, 2000). That portion deposited on land was evenly distributed between cropland, improved pasture/hay, and unimproved pasture.

VA DGIF also provided a summary of literature values for population densities of raccoons, beavers, and muskrats. (Farrar, personal communication, August 10, 2000). Below are the average densities used to develop population estimates based on habitat:

- 0.07031 raccoons per square mile
- 5 beaver per mile of stream
- 2.26 muskrat per mile of marsh.

This information was combined with land use data and stream length to develop estimates of raccoons, beavers, and muskrats in the watershed. Note, to estimate beavers in the watershed, an assumption was made that only 25 percent of the stream is suitable habitat for beaver. (Burt, 2000)

Tables 3-5 through 3-7 present species specific estimates of available habitat, number of animals, fecal coliform generation rates, and percentage breakouts for direct and indirect deposition.

Table 3-5. Wildlife Habitat Estimates

Model Segment (Sub-Watershed)	Deer Habitat (acres)	Goose Habitat (acres)	Raccoon Habitat (acres)	Beaver Habitat (acres)	Muskrat Habitat (acres)
HC-1	2,126	1,242	876	0.94	0
HC-2	1,160	648	517	0.53	1
HC-3	2,649	1,497	937	0.78	3
HC-4	4,589	2,457	1,755	0.50	2
Total	**10,524**	**5,845**	**4,085**	**2.75**	**6**

Table 3-6. Wildlife Animal Estimates

Model Segment (Sub-Watershed)	Deer Estimate (animals)	Goose Estimate (animals)	Raccoon Estimate (animals)	Beaver Estimate (animals)	Muskrat Estimate (animals)
HC-1	158	53	62	5	0
HC-2	86	28	36	3	3
HC-3	196	64	66	4	8
HC-4	340	105	123	2	3
Total	**780**	**250**	**287**	**13**	**14**

Table 3-7. Wildlife Fecal Coliform and Direct Deposition Estimates

Animal Type	Fecal Coliform Generation Rate (Counts/Animal/Year)	Percent Direct Deposition	Percent Indirect Deposition
Deer	9.30E+11	2%	98%
Goose	2.63E+07	50%	50%
Raccoon	8.21E+11	2%	98%
Beaver	7.30E+07	100%	0%
Muskrat	6.94E+10	90%	10%

3.2.3 Pets

The Shenandoah County Treasurer's Department was contacted to determine the number of licensed dogs in the county. Based on the number of dogs with licenses, and the population estimates provided by the 1999 US Census, there is one dog for every 4.7 households in Shenandoah County. This density was applied to the entire watershed. Dogs generate 4.50×10^8 counts of fecal coliform per day (Geldreich, 1978). Fifty percent of the fecal content was assumed to be deposited on mixed urban land and the other 50 percent were assumed to be deposited on farmstead land. In sub-watershed HC-1, there was no land in the mixed urban category, therefore all fecal material was considered to be distributed on farmstead land. The estimated number of pets by sub-watershed segment is presented in Table 3-8.

Table 3-8. Pet Population Estimates

Sub-Watershed	Households	Number of Dogs
HC-1	102	22
HC-2	82	17
HC-3	181	38
HC-4	234	49
Total	**599**	**126**

3.2.4 Livestock

Livestock can be broken into two categories: confined animals and unconfined animals. Confined animals (e.g, poultry, dairy cows) are under roof, in a smaller loafing lot, or in a feed lot for a portion of the day. The confined period varies with the animal and individual operation. The manure and associated fecal coliform from these animals are collected and disposed of, typically through land application to farmland. Unconfined animals (e.g., beef cattle, dry milk cows, and heifers) are pastured on larger lots. The manure and associated fecal coliform from these animals is deposited on the fields where the animals are pastured as well as into or in close vicinity of any stream to which the animals have access. This fecal coliform is either incorporated into the soil, deposited directly into the stream, or becomes part of storm runoff during a precipitation event.

Information on livestock in Holmans Creek watershed was collected from multiple sources. The primary sources of data for confined animals were nutrient management plans, provided by Virginia Department of Conservation and Recreation (Marshall, personal communication, May 4, 2000), that existed for farms within the watershed; USGS 7.5 minute quadrangle maps and aerial photography used to identify the location and approximate size of poultry houses; and Virginia Poultry Federation and Rocco Poultry representatives to identify practices used in poultry operations. The Holmans Creek Watershed Coordinator developed estimates for the number of unconfined animals in each sub-watershed based on information from the Lord Fairfax Soil and Water Conservation District, Natural Resources Conservation Service, Holmans Creek Conservation Plans of Operation, and visual counts of animals in each sub-watershed conducted over the last 4 years (Bankson personal communication, July 19, 2000).

Table 3-9 indicates the average weight and waste load for the livestock found in Holmans Creek watershed

Table 3-9. Livestock Weight and Waste Load

Animal	Average Weight (lbs/animal)	Waste Load (lbs/animal/day)
Dairy Cow	1,350	108
Beef Cow	1,000	63
Turkey	15	1.2
Broiler	2.2	0.18

(Source: John Kosco, USEPA)

Confined Livestock

Nutrient management plans within the watershed were used to determine the average amount of manure and litter generated on a per animal basis within the watershed. As nutrient management plans were not available for all farms in the watershed, the number of confined animals was estimated using alternative sources as discussed below.

Dairy Cows

Dairy operations typically confine dairy cows only part of the time. This results in two separate types of loads — both a confined and an unconfined fecal coliform load. This section presents information on the confined load.

There are two dairies in Holmans Creek watershed, both in sub-watershed HC-3. Each dairy was contacted to determine the number of milk cows, dry cows, and heifers at the facility. The number of animals at each dairy can be found in Table 3-10.

Table 3-10. Dairy Animals

Dairy	Milk Cows (number)	Dry Cows (number)	Heifers (number)
Dairy 1	66	5	34
Dairy 2	125	15	100

(Source: owners of both dairies)

Confinement schedules vary from dairy to dairy and for milk cows, dry cows, and heifers. Milk cows at Dairy 1 are confined for a portion of the time, while Dairy 2 confines milk cows all of the time. Both dairies confine dry cows and heifers 2 percent of the time. Dry cows and heifers were not included as confined animals and are discussed under unconfined livestock. Table 3-11 shows a typical dairy cow confinement schedule on a monthly basis. The owner of Dairy 1 indicated that milk cows are confined 60% of the time and are unconfined (pastured) 40% of the time. These rates vary slightly over the course of a year, slightly higher in the winter months and lower in the summer months. A monthly confinement schedule is presented in Table 3-11. This schedule was applied to milk cows confined in Dairy 1.

Table 3-11. Confinement Rate for Dairy Cows

Month	Percentage of Time Confined
January	75 %
February	75 %
March	75 %
April	60 %
May	50 %
June	50 %
July	50 %
August	50 %
September	50 %
October	50 %
November	60 %
December	75 %

(Source: owners of both dairies)

Dairy 1 has a current nutrient management plan that included detail on the amount of manure collected. A manure production rate per milk cow was calculated based on the existing nutrient management plan and the confinement rate, and was then applied to the number of milk cows at Dairy 2. This generated an estimate of the manure produced and collected during confinement. Note that fecal coliform production for the time periods where dairy herds are pastured is considered an unconfined source and discussed under unconfined livestock.

Poultry

Information on poultry operations was collected from nutrient management plans within the watershed. These plans were used to develop an average litter production rate on a per animal basis. An examination of the 1994 USGS 7.5-minute quadrangle maps and USGS 1997 aerial photography of the watershed showed that there were a significant number of poultry houses that were not currently being captured by nutrient management plans, therefore the maps, aerial photography, and public comments were used to estimate the number and size of poultry houses in each sub-watershed.

Based on information provided by the Virginia Poultry Federation (Bauhan, personal communication, August 4, 2000) and Rocco Poultry (Maupin personal communication, August 4, 2000), any house under 600 feet long was considered a broiler house and any house longer than 600 feet was considered a turkey house. Broiler operations move 7 flocks of broilers through a house each year, with the house being occupied for 287 days. Based on this schedule, there is an average population of 25,144 broilers/house/year. Turkey operations use a staggered, overlapping schedule to move five flocks through a house in a year. Based on this schedule, there is an average population of 15,346 turkeys/house/year. The average litter production rates developed using the nutrient management plans was applied to these poultry estimates to determine the total amount of poultry litter generated in each sub-watershed segment.

Table 3-12 contains information on the numbers of animals in each sub-watershed and the associated amount of manure and litter that is applied to fields within Holmans Creek watershed.

Table 3-12. Confined Animals in Holmans Creek Watershed

Segment	Number of Animals	Animal Type	Manure/Litter Generated	Units
HC-1	201,152	Broiler	1,238	tons
HC-2	61,384	Turkey	2150	tons
	150,864	Broiler	929	tons
HC-3	191	Dairy (milk cows)	1,212	kgal
	50,288	Broiler	310	tons
	30,692	Turkey	1,075	tons
HC-4	502,880	Broiler	3,096	tons
	46,038	Turkey	1,612	tons

(Source: USGS 7.5 minute quadrangle maps, USGS aerial photography, and nutrient management plans)

Manure and Litter

The manure and litter that are generated by confined animals are collected and applied to crop, pasture, and orchard land. In the Holmans Creek watershed, there are approximately 1,229 acres of cropland, 5,804 acres of pasture, and 826 acres of orchard. Based on conversations with Bobby Clark, the Shenandoah County Cooperative Extension Agent, 90% of cropland is in a corn-small grain rotation and 10% of the cropland is planted in soybeans. In the corn-small grain rotation, corn for silage is planted between the middle of April and the middle of May. Seventy to eighty percent of the corn is planted using no-till farming techniques. The corn is then harvested from the middle of August through September. In October, small grains such as wheat, rye, or barley are planted, typically using conventional tillage methods (e.g., disking) and are harvested in April.

Tables 3-13, 3-14, 3-15 and 3-16 provide information on the land application rates of litter and manure applied to the different land uses. These estimates were developed based on information provided by VA DCR nutrient management specialist (Marshall personal communication, May 4, 2000) and verbal comments provided during public meetings (July 17, 2000).

Confined livestock provides manure available for application within Holmans Creek. An application schedule based on suggested application rates in nutrient management plans and anecdotal data from residents was developed. In this schedule, cropland receives application twice a year; pasture and orchards receive application once a year. Table 3-17 details the acreage of cropland, improved pasture/hay and orchards receiving manure and litter application.

Table 3-13. Amount of Each Land use Receiving Application

Land use	Percent Receiving Application
Cropland	75%
Improved Pasture/Hay	50%
Unimproved Pasture	0%
Orchard	60%

(Source: Nutrient Management Plans)

Table 3-14. Land Application Schedule – Poultry Litter

Month	Amount of Litter Applied	Land Use Receiving Litter*
January	1%	Improved Pasture/Hay, Cropland
February	3%	Improved Pasture/Hay, Cropland
March	11%	Cropland, Orchard, Improved Pasture/Hay
April	20%	Cropland, Orchard, Improved Pasture/Hay
May	20%	Cropland, Orchard, Improved Pasture/Hay
June	2%	Improved Pasture/Hay
July	2%	Improved Pasture/Hay
August	5%	Improved Pasture/Hay
September	15%	Improved Pasture/Hay, Cropland
October	15%	Cropland
November	3%	Cropland
December	3%	Improved Pasture/Hay, Cropland

* Land uses listed in order of application priority
(Source: Jay Marshall, VA DCR)

Table 3-15. Land Application Schedule – Dairy Manure

Month	Amount of Manure Applied	Land Use Receiving Manure
January	0%	
February	3%	Cropland
March	20%	Cropland
April	27%	Cropland
May	10%	Cropland
June	0%	
July	0%	
August	3%	Cropland
September	15%	Cropland
October	12%	Cropland
November	10%	Cropland
December	0%	

(Source: Jay Marshall, VA DCR)

Table 3-16. Manure and Litter Application Rates

Animal (Units)	Cropland Application Rate	Improved Pasture Application Rate	Orchard Application Rate
Dairy Cows (gal/acre)	6,000	6,000	0
Broilers (tons/acre)	3	2	1
Turkeys (tons/acre)	3	2	1

(Source: Jay Marshall, VA DCR; public comments to July 17, 2000 meeting)

Table 3-17. Acres Receiving Manure and Litter Application

Sub-watershed	Cropland Receiving Application (Acres)	Orchard Receiving Application (Acres)	Improved Pasture/Hay Receiving Application (Acres)
HC-1	102	27	578
HC-2	63	310	225
HC-3	259	71	611
HC-4	498	86	1,174

There is less than three percent difference between the amount of poultry litter needed for application to farmland and the amount of poultry litter generated in the watershed, indicating that approximately 267 tons of poultry litter is imported into the watershed. It was estimated that manure is imported into the watershed to supplement fertilization practice based on availability of resource and cost savings compared to chemical based fertilizing.

Fecal Coliform Loads Applied To Fields

Manure collected from dairy and poultry operations is stored for a period of time before application to crop and pastureland. During this storage period, fecal coliform rates will decrease as the organisms begin to "die-off." The variable fecal coliform concentration surviving the storage period can be estimated using a first-order equation. The assumptions used to reflect this storage die-off and adjust the load of fecal coliform being land applied are described below:

- The fecal coliform generation rates are:
  - Chickens – 2.40×10^8 counts/animal/day
  - Cows – 5.40×10^9 counts/animal/day
  - Turkeys – 1.30×10^8 counts/animal/day (Metcalf and Eddy, 1979)
- Manure and litter are generated at equal rates throughout the course of the year.
- Die-off can be estimated using the formula: $C = C_o\ e^{(-kt)}$

  Where:
  C is the concentration of fecal coliform in the stored litter/manure
  C_o is the initial concentration of fecal coliform in the stored litter/manure
  k is the decay rate
  t is time in days
- The decay rate (k) used for poultry is 0.08 (Giddens, 1973)
- The decay rate (k) used for dairy is 0.375 (Coles, 1973)
- As litter/manure is removed from the storage facility, there is a constant concentration of fecal coliform throughout the material.
- At the end of the spring application, all manure/litter storage facilities are empty.

Based on the above information and assumptions, the fecal coliform being generated, stored, reduced via die-off, and applied to crop and pasture lands was calculated for each sub-watershed on a monthly basis.

Unconfined Livestock

Unconfined livestock consists primarily of beef cattle throughout the entire Holmans Creek watershed and dairy cows in sub-watershed HC-3. The Holmans Creek Watershed Coordinator developed estimates for unconfined animals in each sub-watershed based on information from the Lord Fairfax Soil and Water Conservation District, Natural Resources Conservation Service, Holmans Creek Conservation Plans of Operation, and visual counts of animals in each sub-watershed conducted over the last four years (Bankson personal communication, July 19, 2000).

Dairy Cows

Dairy operations typically confine dairy cows only part of the time. This results in two separate types of loads – both a confined and an unconfined fecal coliform load. This section presents information on the unconfined load (see sections 4.4.4 and 4.4.5 for details on dairy cows during confinement and for details on how the animals are apportioned between confined and unconfined).

During the period of time that dairy cows are unconfined, the manure is deposited on unimproved pastureland. See section 4.2.4.1 for details on how the animals are apportioned between confined and unconfined. Based on conversations with both dairy owners, dry cows and heifers at each facility are unconfined (i.e., pastured) 98 percent of the time. For this analysis, dry cows and heifers were considered to be unconfined animals.

Beef Cattle

Beef cattle are always unconfined in Holmans Creek. Beef cattle generate 63 lbs. of manure and 5.40×10^9 counts fecal coliform per animal per day. Beef cattle manure is deposited on both improved pasture and unimproved pasture. For the purpose of this TMDL, it is assumed that the time spent by beef cattle on each of these land uses is approximately equal. The number of beef cattle and the amount of manure generated are presented in Table 3-18. The number of cattle in sub-watershed HC-3 also includes dry cows and heifers from dairy operations. The dairy operation's confinement practices and manure deposition are similar to beef cattle.

Table 3-18. Manure and FC Generated by Beef Cattle

Sub-watershed	Beef Cattle	Manure Generated (tons/year)
HC-1	280	3,222
HC-2	346	3,981
HC-3	854	9,826
HC-4	430	4,947
Total	**1,910**	**21,976**

Direct and Indirect Unconfined Loads from Dairy Cows and Beef Cattle

Unconfined animals contribute two different types of loads to Holmans Creek; the direct load that occurs when they have access to the stream, and the indirect load that occurs when they are pastured. There are three factors that drive the amount of manure that is directly deposited to a stream: the number of animals that physically have access to the stream, the time of the year, and how long the cattle choose to spend in close vicinity to the stream (Larsen et. al 1993, Biskie et al, 1988).

The following assumptions were made regarding cattle in the stream:

- 40 percent of the cattle in Holmans Creek watershed have been fenced, and therefore, do not have access to the stream. (Bankson, personal communication, July 19, 2000)
- 10 percent of excrement that occurs while cattle are in close vicinity to the stream results in direct deposition. (BSE, 2000)
- Time spent in the stream for dairy and beef as shown in Table 3-19 (Maptech, 2000)

Table 3-19. Hours/Day Beef and Dairy Cows Spend In and Around the Stream.

Month	Beef	Dairy
January	1	0.5
February	1	0.5
March	1.5	1
April	2	1.5
May	2	1.5
June	2.5	2
July	2.5	2
August	2.5	2
September	2	1.5
October	1.5	1
November	1.5	1
December	1	0.5

(Source: Maptech, 2000a, 2000b)

All of these data, estimates, and assumptions described for each source are used to approximate the amount of fecal coliform generated on a daily basis within the watershed. These values are then incorporated into a model in to determine the amount of fecal coliform reaching the waters of Holmans Creek. The modeling approach is described in the following section.

4. Modeling Approach for Holmans Creek Total Maximum Daily Load

The most critical component of Total Maximum Daily Load (TMDL) development is to establish the relationship between the source loadings and the in-stream water quality. This relationship is essential for the evaluation and identification of management options that will achieve the desired source load reductions. Modeling the relationship between loads and water quality can be achieved through different techniques ranging from simple mass balance models to more sophisticated dynamic and fully integrated watershed scale modeling. However, when the fate and transport of a pollutant depends upon the changing responses to runoff flow and source loadings, it is important to use a model that simulates the loadings from point and non-point sources and characterizes the resulting stream water quality for the different runoff and stream flows that may occur in the watershed.

This section describes the steps to select a model, develop the information used in the model and hydrologic and water quality simulations of Holmans Creek. It details the modeling tools used, the existing physical and hydrologic data, the hydrology approach used for the calibration and validation, the development of direct and indirect source loadings used in the water quality model, and the approach used for the water quality calibration of the model.

4.1 Model Description

The model selected for Holmans Creek is Hydrologic Simulation Program – Fortran (HSPF). HSPF is a set of computer programs that simulate the hydrology of the watershed, nutrient and sediment nonpoint sources loads, and the transport of these loads in rivers and reservoirs. HSPF partitions the watershed into four smaller units or sub-watersheds. Data on land uses (such as cropland, pasture, forest, and urban) and point and nonpoint sources are entered into the model for each sub-watershed.

The model generates daily nonpoint source edge-of-stream pollutant loads for each land use and instream concentrations at each sub-watershed outlet. Each sub-watershed contains information generated by a specific component or submodel. Results from the three submodels (hydrologic submodel, non-point source submodel, and river submodel) combine to estimate the changes in load estimates to Holmans Creek. The hydrologic submodel uses rainfall and other meteorological data to calculate runoff and subsurface flow for all the watershed land uses. The runoff and subsurface flows, generated by the hydrologic sub-model, ultimately drive the nonpoint source sub-model. The nonpoint source sub-model simulates soil erosion and the pollutant loads from the land to the edge of the stream. The river sub-model routes flow and associated pollutant loads from the land through the lakes, rivers, and reservoirs to the outlet of the watershed.

4.2 Selection of Land Use for Each Sub-watershed

Land use data were prepared by the DCR. Digital ortho quarter quadrangle images were used to both obtain watershed and sub-watershed boundaries and assist in the classification of land uses. DCR was able to classify the land uses for 92 percent of the coverage based on images that were 2-3 years old, and worked with the Holmans Creek Watershed Committee coordinator, Rod Bankson, to ground truth the remaining eight percent (Bankson, personal communication, April 30, 2000). The data were obtained from the VA DCR, as an ArcView shapefile. The shapefile's coordinates were in the UTM plane coordinate system, zone 17, in the 1983 North American datum (GRS80 spheroid).

The coverage of the sub-watersheds used for this analysis was generated and intersected with the land use coverage to determine the land use for each sub-watershed. There were 18 different land uses in the original shapefile that were classified into eight land uses. Table 4-1 shows the conversion between the original and the final land uses and Table 4-2 shows the final land uses, by sub-watershed, that were used in the analysis.

4.3 Hydrology Modeling Approach

This section describes the approach used for the hydrology model calibration and validation in Holmans Creek. Simulating the long-term hydrologic response requires extensive information on the physical, meteorological, and hydrological characteristics of the watershed. Precipitation and other meteorological data are the primary driving functions in the HSPF model. Surface runoff, stream flows, nonpoint source loads, and kinetic reaction rates all primarily depend on the continuous hourly input of precipitation, temperature, evaporation, and solar radiation.

Table 4-1. New Land Use Classifications

Original Classification	New Classification
Barren	Forest
Cattle Operations	Farmstead
Commercial & Services	Mixed Urban
Crop Land	Cropland
Farmstead	Farmstead
Forested	Forest
Grazed Woodland	Unimproved Pasture
Improved Pasture / Permanent Hay	Improved Pasture/Hay
Low Density Residential	Mixed Urban
Mixed Urban Or Built-up Land	Mixed Urban
Orchards	Orchard
Poultry Operations	Farmstead
Transportation	Mixed Urban
Unimproved Pasture	Unimproved Pasture
Water/Wetlands	Water
Wooded Residential	Mixed Urban

Acreage for improved pasture and hay assumed to be equal for the Improved Pasture/Hay land use (Bankson, personal communication, April 30, 2000).

Table 4-2. Land Use Classification by Sub-watershed in Acres

New Classification	HC-1	HC-2	HC-3	HC-4	Total
Cropland	136.47	83.89	344.86	664.04	1229.25
Farmstead	122.41	49.65	89.15	104.31	365.52
Forest	753.58	448.22	813.78	1475.07	3490.64
Mixed Urban	0	19.10	33.88	176.03	229.02
Orchard	45.11	517.30	119.06	144.10	825.57
Improved Pasture/Hay	1155.29	449.24	1221.77	2348.21	5174.50
Unimproved Pasture	81.03	178.42	268.45	101.69	629.59
Water	6.09	24.78	3.63	11.65	46.14
Total	**2299.97**	**1770.60**	**2894.59**	**5025.10**	**11990.24**

Model calibration involves comparing the model results with observed data and adjusting key parameters to improve the accuracy of the model results. An acceptable model calibration requires a period long enough (usually several years) to reproduce different hydrologic conditions. The existing flow data at Holmans Creek consisted of a few months of observation (from December 1999 through March 2000) and is inadequate for hydrologic calibration of the HSPF model.

Consequently, a "paired watershed" approach was used for model calibration and validation. This approach uses the key assumption that the "paired watershed" has a long-term hydrologic response similar to the one in Holmans Creek. The following steps summarize the approach:

- Select a watershed that has similar hydrologic and physical conditions and land use to those of the Holmans Creek watershed and that also has long-term observed flow data.
- Develop the HSPF model setup for the selected watershed (physical, hydrologic, and land use data)
- Perform the hydrology calibration and validation on the selected watershed using the long-term stream flow recorded within the selected watershed.
- Transfer the calibrated/validated HSPF dataset to the Holmans Creek watershed. In other words, the simulated hydrologic response is transferred. The model is setup for Holmans Creek using the land use data of Holmans Creek but keeping all other parameters derived from the hydrology calibration and validation in the "paired watershed."

4.3.1 Selection of the Paired Watershed - Linville Creek

The closest USGS discharge station with continuous flow is located on Linville Creek, in Broadway, Virginia (USGS Station Number: 01632082), 10 miles from Holmans Creek. This nearby watershed with continuous flow monitoring provides reasonable assurance of similar precipitation and other weather data. Furthermore, a comparison of some of the more significant factors affecting runoff characteristics, presented in Table 4-3, indicates that the Linville and Holmans watersheds have similar hydrologic and physical characteristics. Two factors, drainage area and the percentage of forested land are not similar.

The drainage area of Linville Creek is larger than Holmans Creek, while the percent of land use as forest in Linville is smaller than in Holmans. However, these differences did not affect the overall hydrologic response since the calibrated and validated dataset from Linville Creek was adjusted to reflect the existing total drainage area and land use distribution in Holmans Creek. Thus, the Linville Creek watershed can be used to adequately represent the hydrologic response in Holmans Creek for the purposes of the hydrology calibration and validation.

Table 4-3. Linville and Holmans Watershed Characteristics

Characteristic	Holmans Creek Watershed	Linville Creek Watershed
Drainage Area	12,000 acres [a]	29,120 acres
Channel Length	12.75 miles [b]	15 miles [b]
Channel Slope	0.5 % [b]	0.8 % [b]
Percent Forested	27 % [a]	14 % [b]
Average Overland Flow Slope	6.4 % [b]	5.9 % [b]

[a] Source: VA DCR land use data
[b] Source: USGS topographic 7.5 minute quadrangle maps

The Linville Creek watershed has been used as a "paired watershed" for several TMDLs in the Shenandoah Valley. A hydrology simulation of the Linville watershed by a calibrated/validated HSPF already existed. The Biological Systems Engineering (BSE) Department at Virginia Polytechnic and State University provided the Linville Creek watershed HSPF calibrated dataset, the corresponding precipitation, and other available weather data. The hydrology validation presented in this report uses different time periods than the one previously used by BSE.

4.3.2 Hydrology Calibration

Hydrology calibration of the model compares simulated stream flow data to observed data. The model assumptions for hydrology are adjusted within reasonable ranges to achieve a good agreement in the comparison. The Linville Creek stream flow data and the precipitation records from the Dale Enterprise weather station for the Linville Creek watershed provided by BSE span the period from 1985 to 1996. The period of record selected for the calibration spans from January 1, 1990 to December 31, 1994. This 5-year period was selected because it includes both dry and wet years covering different hydrologic conditions, and are representative of the majority of weather patterns for Holmans Creek.

A comparison of the simulated and observed flow data indicates that the model calibration is robust and adequately reproduces the hydrologic response of the Linville Creek watershed. There is a very good agreement between observed and simulated flow as shown in Figure 4-1.

Linvile Watershed - Hydrology Calibration 1990-1994

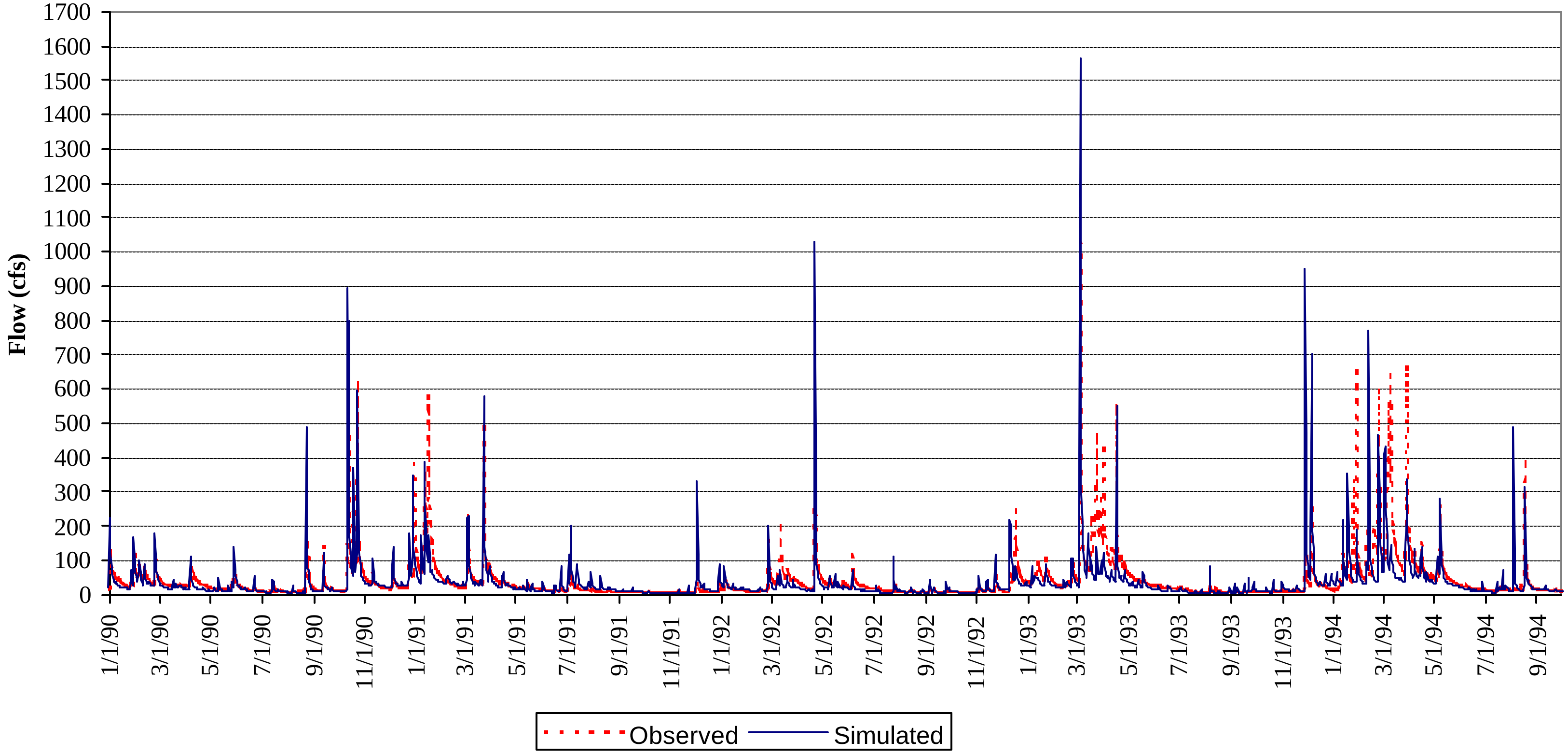

Figure 4-1. Simulated and Observed Flow During the Calibration Period

Using 50 cfs as a storm event baseline, the number of observed storm events was determined to be 78 storms over the 5-year period. The number of simulated storm events produced by the hydrology calibration was 88 storms over the 5-year period, thus showing the accuracy of the calibration. The accuracy of the hydrology calibration was further analyzed by using percent error criteria provided in the USGS Users Manual for an Expert System for Watershed Model Calibration (Lumb, 1993). These error criteria are based on the percent error between the observed and simulated flows for various periods. For instance, Table 4-4 compares the observed and simulated flow for each year during the calibration period as well as the total volume of water during this period. It indicates that the percent error (–2.2 percent) on the total simulated flow is well within the acceptable error of ±10 percent. This demonstrates the robustness of the calibration in reproducing the total flow during the period of 1990 to 1994. Table 4-5 presents similar statistics but compares the simulated and observed summer flows. The summer low-flows are important when implementing a TMDL, since most of the low or critical flows occur during this season. Additionally, analysis of observed data from Holmans shows the summer months (June through August) as having a higher incidence of fecal coliform water quality standard violation. Table 4-6 indicates that the simulated total summer streamflow during the calibration period compares very well with the corresponding observed flow with the model error less than one percent.

Comparing the total and summer volume of simulated and observed flows does not give a good indication on the robustness of the simulation to reproduce the whole range of observed flows. For this purpose, a frequency distribution analysis was developed on the complete range of observed and simulated flows during the calibration period. The DURANL (Duration Analysis) module/component of the HSPF model was used to generate these statistics. Figure 4-2 shows the result by providing the cumulative frequency distributions of the observed and simulated flows. The goodness of fit between the two frequency distributions indicates that the model strongly reproduces the complete range of flows.

Table 4-6 supplements the data shown in Figure 4-2 and gives further indication of the robustness of the calibration. It depicts the cumulative simulated and observed flows at different frequency ranges. Cumulative observed and simulated flows are in a very good agreement and well within acceptable criteria.

Table 4-4. Linville Creek Hydrology Calibration – Annual and Total Flows

Year	Observed (inches)	Simulated (inches)	Percent Error	Criteria (%)
90	11.02	11.67	5.98	
91	9.51	9.87	3.79	
92	7.80	7.51	-3.74	
93	14.69	15.22	3.63	
94	16.83	14.22	-15.50	
Total	**59.85**	**58.50**	**-2.25**	**10**

Table 4-5. Linville Creek Summer Hydrology Calibration Results

Year	Summer Observed (inches)	Summer Simulated (inches)	Percent Error	Criteria (%)
90	1.19	1.44	21.2	
91	1.04	1.53	46.6	
92	1.27	0.99	-22.3	
93	1.05	0.93	-11.0	
94	1.77	1.38	-22.2	
Total	**6.32**	**6.26**	**0.85**	**15**

Table 4-6. Calibration Summary Statistics on Selected Cumulative Flow Ranges (1990-1994)

Flow Frequency	Observed (inches)	Simulated (inches)	Percent Error	Criteria (%)
Highest 10%	28.65	27.44	-4.23	15
Highest 30%	45.38	43.27	-4.64	NA
Highest 50%	52.30	50.40	-3.64	NA
Lowest 50%	7.52	8.14	8.16	10
Highest 70%	56.49	55.05	-2.55	NA

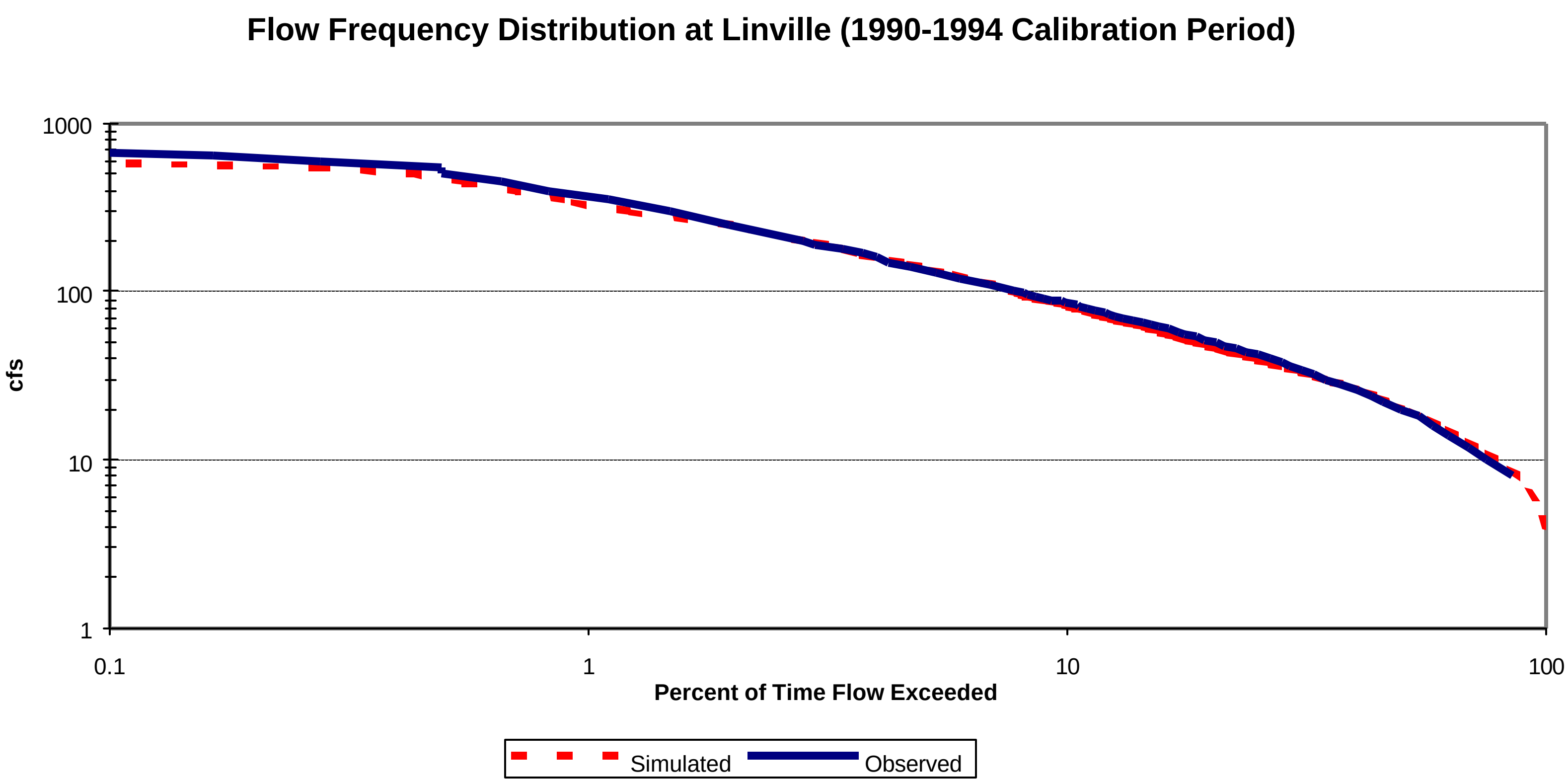

Figure 4-2. Hydrology Calibration – Cumulative Frequency Distribution on the Simulated

4.3.3 Hydrology Validation

This section describes the hydrology validation applied to the Linville Creek Watershed data for use in the Holmans Creek TMDL. The validation process must use a different simulation period than that used for the calibration. The objective is to confirm that the model elements developed during the calibration process will result in a good agreement between observed and simulated flows under different conditions. The selection of the validation period was driven by the time period where water quality data were collected in Holmans Creek. In fact, most of the fecal coliform observations were recorded between 1995 and 1999. The precipitation and other meteorological data provided by BSE and used in the calibration process cover the period from 1985 to 1996. Consequently, it was necessary to obtain meteorological and stream flow data for the period that coincides with the time period when water quality data were recorded.

Hourly rainfall data from 1996 to 2000 were acquired for the Dale Enterprise weather station. However, hourly rainfall data were missing for several periods of time between 1996 and 1998. When contacted, the main observer at the Dale Enterprise weather station could only provide daily total precipitation and not the hourly distribution necessary for the model for those specific periods (Richard Weaver, personal communication, November 30, 2000). National Oceanic and Atmospheric Administration staff recommended using precipitation data from the Star Tannery weather station located in northern Shenandoah County – approximately 20 miles north of Holmans Creek (Scott Stephens, personal communication, December 3, 2000). The rainfall data from the Star Tannery weather station provided complete hourly precipitation records from January 1, 1996 through June 30, 2000. These data were used to fill in for the missing hourly rainfall data in the Dale Enterprise precipitation dataset.

Other weather data (solar radiation, air temperature, dew point, cloud cover, evapotranspiration, and wind speed) used for the hydrology validation are a subset of a larger Water Data Management (WDM) file previously developed by SAIC for the EPA Chesapeake Bay Office in Annapolis, Maryland (USEPA, August 1999). This subset spans the period from 1986 to 1998 and contains complete meteorological data specific to the Shenandoah Basin. Fairly recent weather data from January 1999 to March 2000 were not available. Consequently, the weather data, for the 13-year period (1986 to 1998), in the Shenandoah Basin WDM file, was used to derive seasonal weather data by using average values from 1986 to December 1998. These weather data reflect the long-term average weather condition in Holmans Creek from December to March.

The hydrology simulations were validated for the period of January 1997 to September 1999. The results of the validation process are presented in Figure 4-3 and show a very good agreement between observed and simulated flows. Similar diagnostic tools as those used for the calibration process are presented. Table 4-7 depicts the comparison between simulated and observed annual and total flows. Table 4-8 presents statistics on the summer flows during the validation period. Table 4-9 depicts the corresponding statistics on selected cumulative flow ranges between 1997 and 1999 and Figure 4-4 presents the cumulative frequency distributions of observed and simulated flows. Overall these results indicate a robust and strong hydrology calibration and validation. Consequently, the calibrated and validated HSPF hydrology dataset for the Linville Creek can be transferred and adjusted to the Holmans Creek Watershed to simulate the long-term hydrologic response in this watershed.

4.3.4 Summary of Key Hydrology Model Parameters Adjusted in the Calibration

The primary parameters adjusted during the calibration and validation were the infiltration capacity (INFLT), the recession rate for groundwater (AGWRC), and the fraction of deep inactive groundwater inflow (DEEPFR). Other parameters adjusted during the calibration include the recession rate for interflow (IRC), the amount of evapotranspiration from the root zone (LZTEP), the amount of interception storage (CEPSC), and the amount of soil moisture storage in the upper zone (UZSN) and the lower zone (LZSN). The final calibration values of all hydrology parameters are provided in Tables 4-10 through 4-12.

4.3.5 Application of the Hydrology Calibration to Holmans Creek

Prior to transferring the calibrated dataset to Holmans Creek, it is necessary to develop model input variables that are specific to the watershed. Such variables are physically based and consist mainly of the model F-Tables that describe the flow response at each sub-watershed

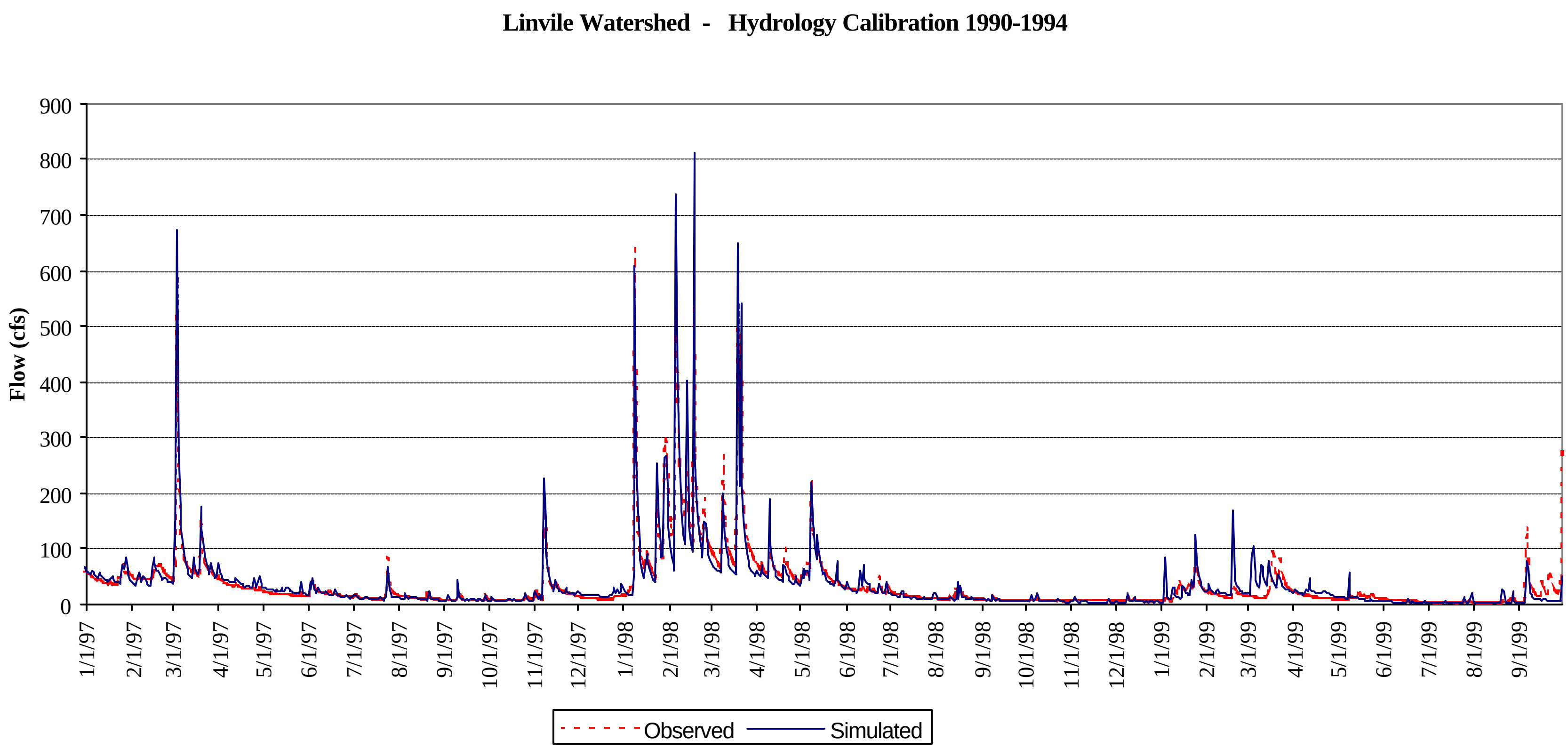

Figure 4-3. Linville Creek Hydrology Validation

Table 4-7. Linville Creek Hydrology Validation – Annual and Total Flows

Year	Observed (inches)	Simulated (inches)	Percent Error	Criteria (%)
97	8.74	9.61	9.87	
98	16.38	15.61	-4.71	
99	3.94	4.11	4.30	
Total	**29.06**	**29.32**	**0.90**	**10**

Table 4-8. Linville Creek Summer Hydrology Validation Results

Year	Summer Observed (inches)	Summer Simulated (inches)	Percent Error	Criteria (%)
97	1.23	1.08	-11.9	
98	1.36	1.32	-3.0	
99	0.36	0.33	-9.0	
Total	**2.95**	**2.73**	**-7.4**	**10**

Table 4-9. Validation Summary Statistics on Selected Cumulative Flow Ranges (1997-1999)

Flow Frequency	Observed (inches)	Simulated (inches)	Simulated % Error	Criteria
Highest 10%	13.51	13.32	1.35	15%
Highest 30%	21.42	22.15	3.45	—
Highest 50%	25.39	25.63	0.94	—
Lowest 50%	3.67	3.29	10.28	10%
Highest 70%	27.74	27.33	1.44	—

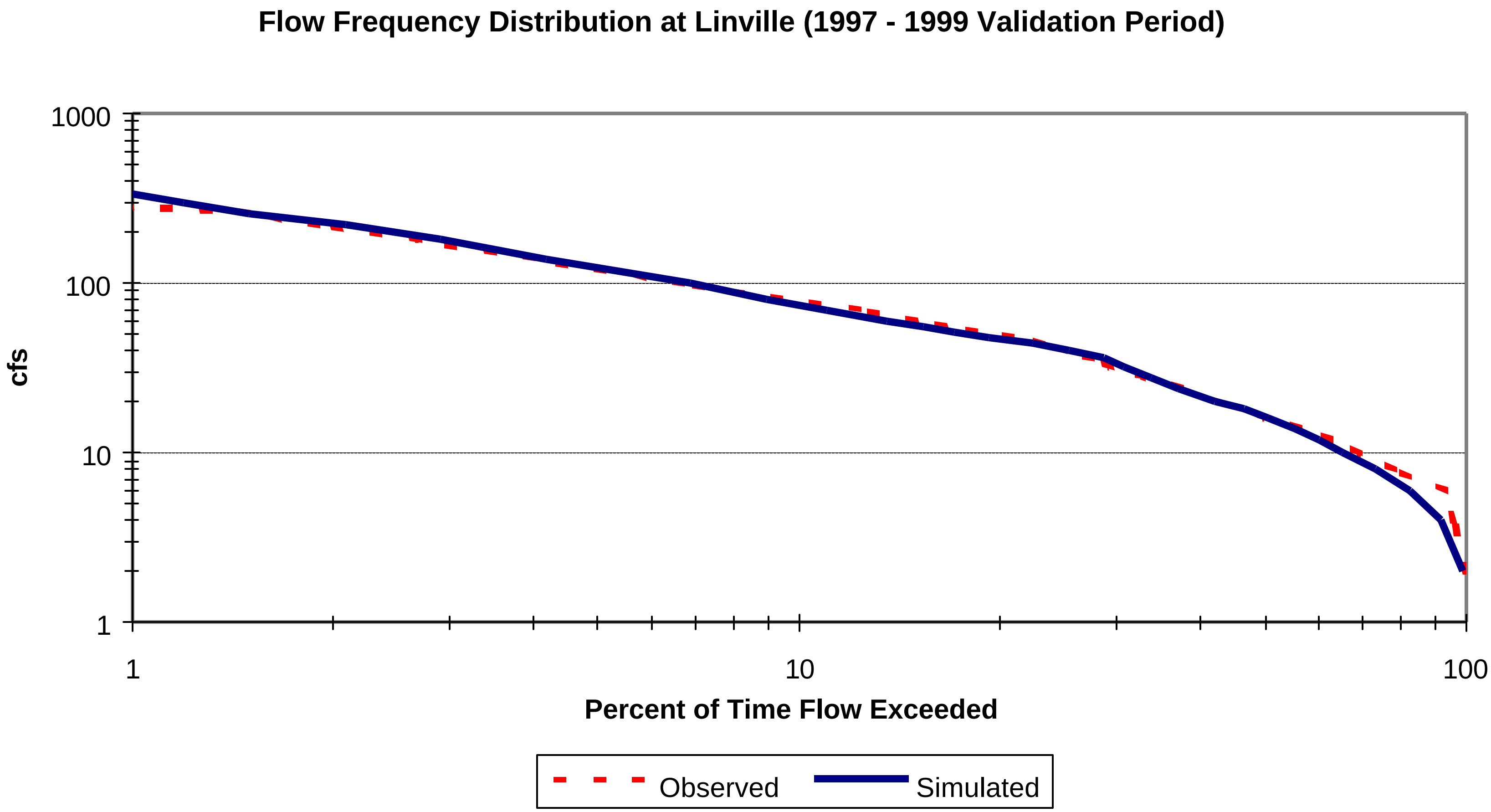

Figure 4-4. Hydrology Validation – Cumulative Frequency Distribution on the Simulated and Observed Flows

Table 4-10. Final Calibration Values for PWAT-PARM2

Parameter	Definition	Units	Final HSPF Values Used for Each Land Use							HSPF Default Values	HSPF Range of Values	
			Forest	Cropland	Orchard	Improved Pasture/ Hay	Mixed Urban	Unimproved Pasture	Farmstead		Min.	Max.
FOREST	Fraction of PLS covered by forest	none	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.0	1.0
LZSN	Lower zone nominal storage	inches	7.00	7.00	6.00	7.00	6.00	7.00	6.00	none	0.01	100.0
INFILT	Index to the infiltration capacity of the soil	in/hr	0.07	0.07	0.04	0.07	0.04	0.07	0.04	none	0.0001	100.0
LSUR	Length of the assumed overland flow plane	feet	300.00	300.00	300.00	300.00	300.00	300.00	300.00	none	1.0	none
SLSUR	Slope of the overland flow plane	none	0.01	0.01	0.01	0.01	0.01	0.01	0.01	none	0.000001	10.0
KVARY	Parameter which affects the behavior of groundwater recession flow, enabling it to be non-exponential in its decay with time	1/in	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.0	none
AGWRC	Basic Groundwater recession rate if KVARY is zero and there is no inflow to groundwater; AGWRC is defined as the rate of flow today divided by the rate of flow yesterday	1/day	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.0	0.001	0.999

Table 4-11. Final Calibration Values for PWAT-PARM3

Parameter	Definition	Units	Final HSPF Values Used for Each Land Use							HSPF Default Values	HSPF Range of Values	
			Forest	Cropland	Orchard	Improved Pasture/ Hay	Mixed Urban	Unimproved Pasture	Farmstead		Min.	Max.
PETMAX	The air temperature below which E-T will arbitrarily be reduced below the value obtained from the input time series (only valid with snow)	deg. F	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.0	none	none
PETMIN	The air temperature below which E-T will be zero regardless of the value in the input time series (only valid with snow)	deg. F	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.0	none	none
INFEXP	The exponent in the infiltration equation	none	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.0	0.0	10.0
INFILD	The ratio between the maximum and mean infiltration capacities over PLS	none	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.0	1.0	2.0
DEEPFR	The fraction of groundwater inflow which will enter deep (inactive) groundwater, and thus be lost from the system as it is defined in HSPF	none	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.0	0.0	1.0
BASETP	The fraction of remaining potential E-T which can be satisfied from baseflow (groundwater outflow)	none	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.0	0.0	1.0
AGWETP	The fraction of remaining potential E-T which can be satisfied from active groundwater storage	none	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.0	1.0

Table 4-12: Final Calibration Values for PWAT-PARM4

Parameter	Definition	Units	Final HSPF Values Used for Each Land Use							HSPF Default Values	HSPF Range of Values	
			Forest	Cropland	Orchard	Improved Pasture/ Hay	Mixed Urban	Unimproved Pasture	Farmstead		Min.	Max.
CEPSC	The interception storage capacity	inches	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.0	0.0	10
UZSN	The upper zone nominal storage	inches	1.00	0.98	0.48	0.64	0.48	0.98	0.48	none	0.01	10
NSUR	Manning's n for the assumed overland flow plane	none	0.35	0.25	0.25	0.25	0.20	0.25	0.20	0.1	0.001	1.0
INTFW	The interflow inflow parameter	none	3	1	1	1	1	1	1	none	0.0	none
IRC	The interflow recession parameter (under zero inflow, this is the ratio of today's interflow outflow rate to yesterday's rate)	none	0.75	0.60	0.60	0.60	0.60	0.60	0.60	none	0.0	0.999
LZETP	The lower zone E-T parameter (index to the density of deep rooted vegetation)	none	0.70	0.30	0.30	0.30	0.10	0.30	0.10	0.0	0.0	0.999

outlet. For this purpose, a hydrologic study was conducted in the Holmans Creek watershed from December 1999 through March 2000 (Maptech, 2000b). During this time, data were collected from two precipitation stations, a continuous flow station at the watershed outlet, and five stream gauge stations along Holmans Creek. Figure 4-5 shows the location of each of these stations. The outcome of this study was a three-month record of flow and precipitation data specific to Holmans Creek watershed. The stream gauging measurements along with the continuous flow recording were used to develop the main stage-discharge rating curve at the outlet of the watershed. This information was used to develop the FTABLES input required for the hydrologic simulation of the model. Figure 4-6 depicts the flow stage and precipitation data recorded at Holmans Creek during the period of the study.

During this study observed flow was recorded for a period of three months. As indicated earlier, although this data is inadequate for calibrating and validating the model, the data can be used to further verify the hydrology calibration and validation. Using the calibrated/transferred Holmans Creek data set and appropriate land use distributions and F-Tables, the model was run for the period of 1997 to 2000. In addition, the simulated flow for the period of December 1999 to April 2000 was compared to the corresponding recorded flow during the same period. Figure 4-7 shows the results of this calibration and indicates that there is a good agreement between the two flows, giving further indications of the robustness of the hydrology calibration and validation in Holmans Creek.

4.4 Water Quality Modeling Approach - Source Representation

This section describes the approach taken for modeling the fate and transport of fecal coliform in Holmans Creek. The water quality portion of the model involves a linked two-step simulation process. First the model simulates the FECAL COLIFORM concentration associated with the runoff (PQAL module of the PERLND section). Then this load is transported in the different reaches; a simulation performed using the GQAL module of the RCHRES section.

The PQAL of HSPF is used to simulate the fecal coliform wash-off from the different land uses. The QUALOF option of PQAL is used to simulate the accumulation and removal of fecal coliform from the land by overland flow. This option is used since it accounts for seasonal fluctuations in application rates.

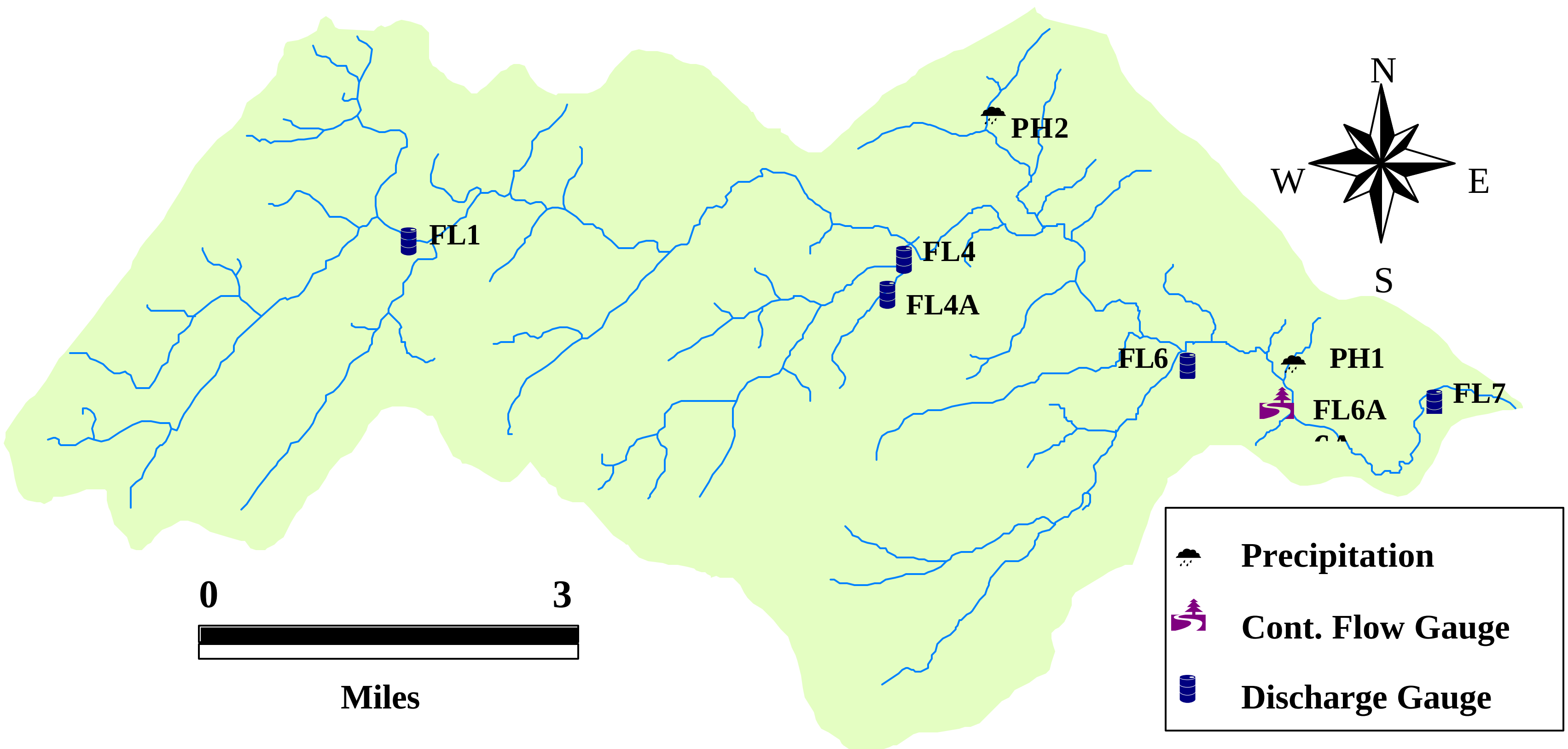

Figure 4-5. Holmans Creek Stream Gauging and Precipitation Station Locations

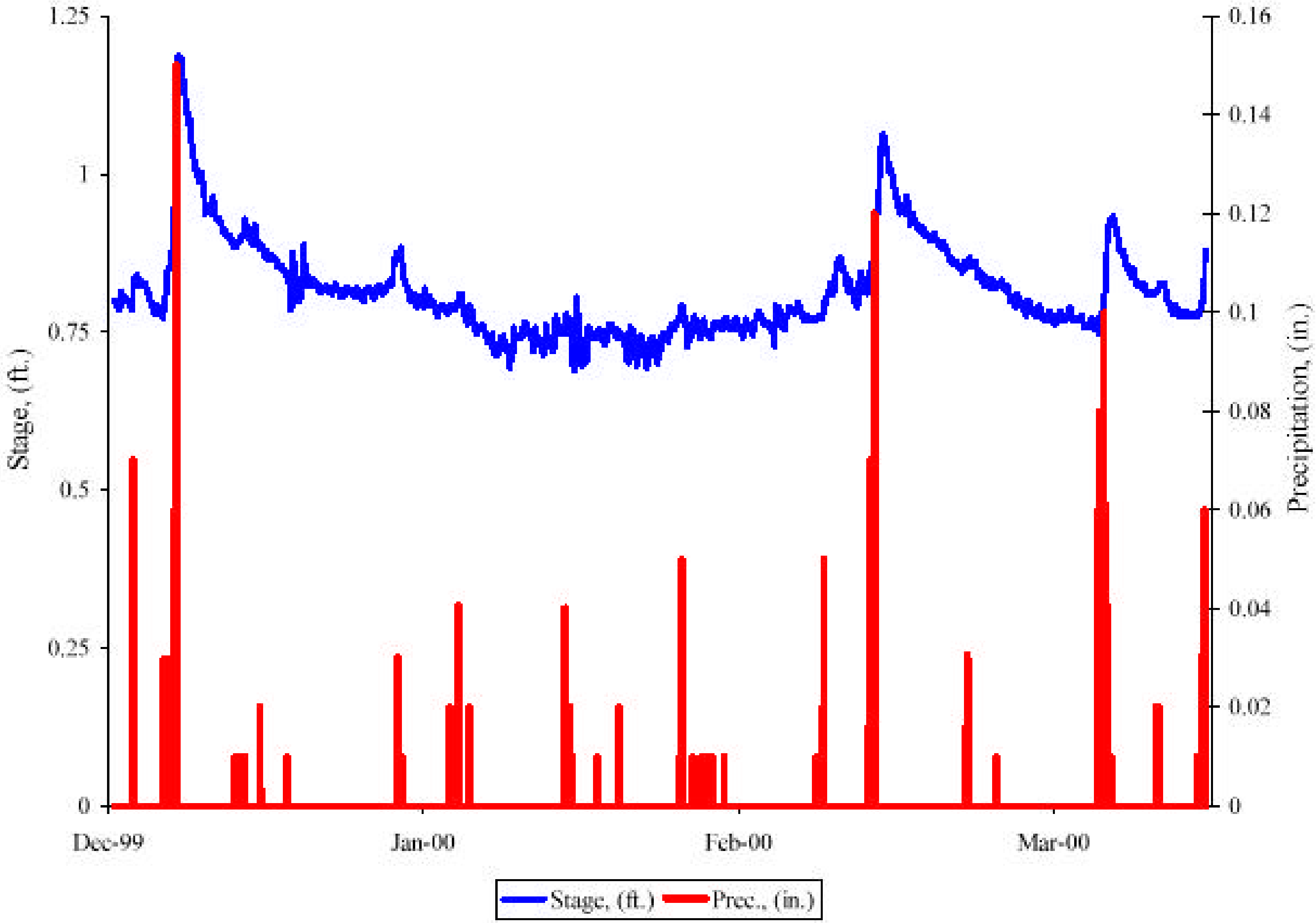

Figure 4-6. Flow Stage and Precipitation in Holmans Creek Watershed

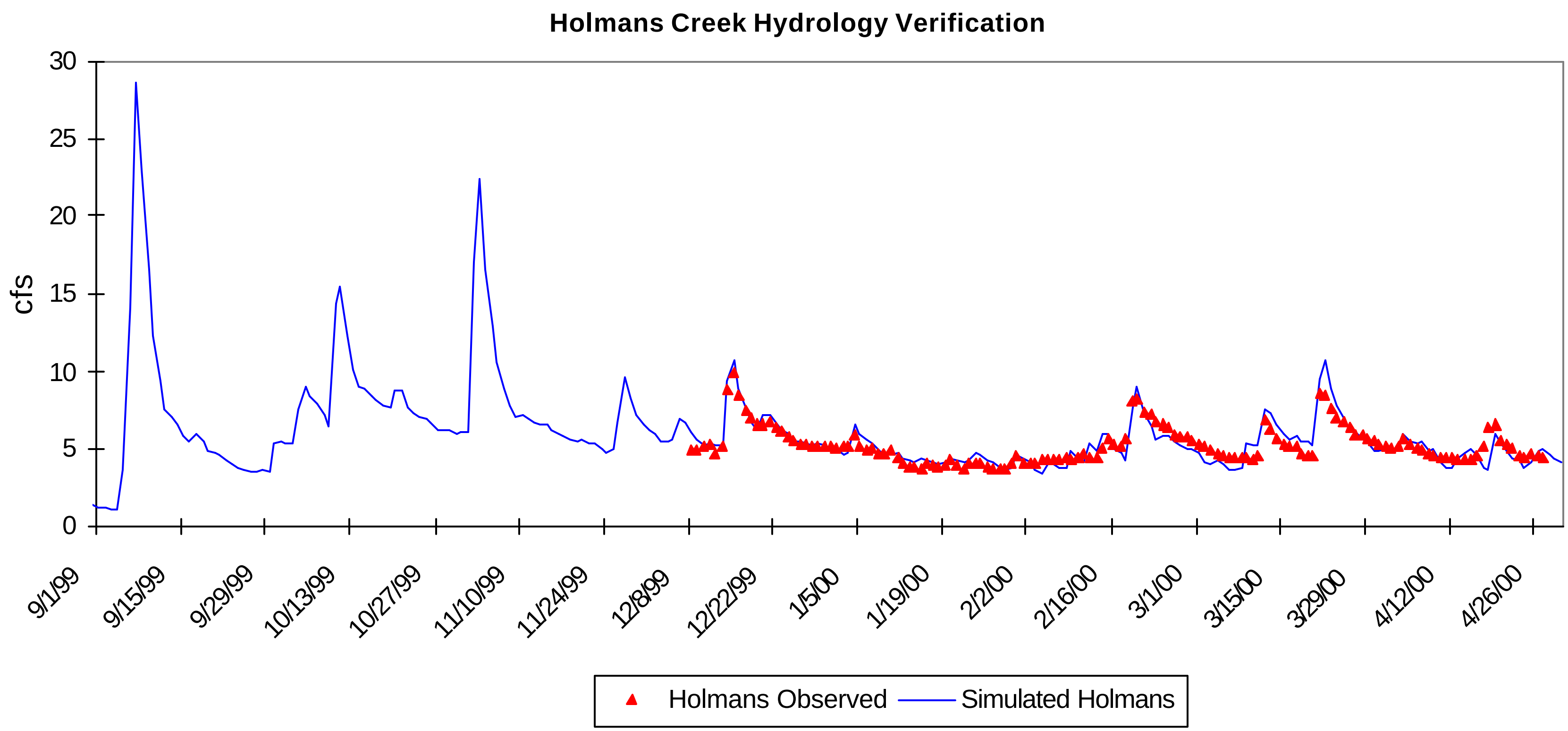

Figure 4-7. Hydrologic Response in Holmans Creek

The fecal coliform associated with the runoff is designated as an indirect source. As indicated in the Source Assessment, sources contributing to the indirect fecal coliform loading in the runoff are wildlife, pets, and livestock. On the other hand, when fecal coliform is directly deposited to the stream it is designated as a direct source. Direct sources can be caused by on-site sewage disposal systems, straight pipes, or by direct deposition in the stream of fecal coliform by wildlife and livestock.

The following sections describe in detail how the fecal coliform loads for direct and indirect sources were developed. Each of the fecal coliform sources previously described is further detailed in the following sections. The loads are presented as counts/year or counts/month by land use in each sub-watershed. Appendix A contains the fecal coliform values used as input into the monthly accumulation tables (MON-ACCUM) of the PQAL section of the model.

4.4.1 Residential Sewage Treatment

The total direct fecal coliform loads to Holmans Creek from septic sources were calculated using 1990 US Census data, the fecal coliform generation rate for humans and the number of failing septic system, derived from USGS household data and the estimated septic system failure rate. Failing septic systems are considered as a direct model-input to the stream meaning that the fecal coliform load per capita already accounts for die-off and transport from the source to the river. The results are presented in Table 4-13.

4.4.2 Wildlife

The fecal coliform loadings by wildlife can be deposited directly and indirectly to Holmans Creek. The following approach was used to derive the wildlife fecal coliform load for each land use in each sub-watershed in Holmans Creek.

The total yearly fecal coliform load (indirect and direct) for each animal type was determined using the animal estimates (for each animal type), their respective fecal coliform generation rates, and the percentage of direct/indirect deposition. Both the indirect and direct fecal coliform loads from wildlife sources for each sub-watershed are presented in Table 4-14.

Table 4-13. Total Fecal Coliform Loads Septic Systems

Sub-watershed	Number of Failing Septic Systems	Number of People Per Household	Fecal Coliform Load Per Capital (counts/day)	Fecal Coliform Load to Stream from Septic Systems (counts/year)
HC-1	31	2.54	2.64E+08	7.54E+12
HC-2	25	2.54	2.64E+08	6.00E+12
HC-3	54	2.54	2.64E+08	1.33E+13
HC-4	70	2.54	2.64E+08	1.72E+13
Total	**180**	2.54	2.64E+08	**4.41E+13**

Totals may not equal due to rounding.
See Appendix C for the conversion of the counts/year to counts/month.

Table 4-14. Direct and Indirect Fecal Coliform Loads from Wildlife Sources

Sub-watershed	Animal Type	Animal Numbers	Fecal Coliform Generation Rate (counts/animal/year)	Percent Direct Deposition	Percent Indirect Deposition	Fecal Coliform Generated by Wildlife (counts/year)	Fecal Coliform Directly Deposited by Wildlife (counts/year)	Fecal Coliform Indirectly Deposited by Wildlife (counts/year)
HC-1	Deer	158	9.30E+11	2%	98%	1.47E+14	2.93E+12	1.44E+14
	Goose	53	2.63E+07	50%	50%	1.40E+09	6.99E+08	6.99E+08
	Raccoon	62	8.21E+11	2%	98%	5.06E+13	1.01E+12	4.96E+13
	Beaver	5	7.30E+07	100%	0%	3.29E+08	3.29E+08	0.00E+00
	Muskrat	0	6.94E+10	90%	10%	0.00E+00	0.00E+00	0.00E+00
Total						**1.97E+14**	**3.95E+12**	**1.93E+14**
HC-2	Deer	86	9.30E+11	2%	98%	8.00E+13	1.60E+12	7.84E+13
	Goose	28	2.63E+07	50%	50%	7.29E+08	3.65E+08	3.65E+08
	Raccoon	36	8.21E+11	2%	98%	2.98E+13	5.96E+11	2.92E+13
	Beaver	3	7.30E+07	100%	0%	1.86E+08	1.86E+08	0.00E+00
	Muskrat	3	6.94E+10	90%	10%	1.81E+11	1.63E+11	1.81E+10
Total						**1.10E+14**	**2.36E+12**	**1.08E+14**
HC-3	Deer	196	9.30E+11	2%	98%	1.83E+14	3.65E+12	1.79E+14
	Goose	64	2.63E+07	50%	50%	1.68E+09	8.42E+08	8.42E+08
	Raccoon	66	8.21E+11	2%	98%	5.40E+13	1.08E+12	5.30E+13
	Beaver	4	7.30E+07	100%	0%	2.74E+08	2.74E+08	0.00E+00
	Muskrat	8	6.94E+10	90%	10%	5.21E+11	4.69E+11	5.21E+10
Total						**2.37E+14**	**5.20E+12**	**2.32E+14**
HC-4	Deer	340	9.30E+11	2%	98%	3.16E+14	6.33E+12	3.10E+14
	Goose	105	2.63E+07	50%	50%	2.76E+09	1.38E+09	1.38E+09
	Raccoon	123	8.21E+11	2%	98%	1.01E+14	2.03E+12	9.92E+13
	Beaver	2	7.30E+07	100%	0%	1.75E+08	1.75E+08	0.00E+00
	Muskrat	3	6.94E+10	90%	10%	2.36E+11	2.12E+11	2.36E+10
Total						**4.18E+14**	**8.57E+12**	**4.09E+14**

Totals may not equal due to rounding.

Next, the total fecal coliform loads for each animal type is distributed over each of the land use categories that it naturally occupies. Each animal type is evenly distributed over each of the land use categories that it naturally occupies and the total fecal coliform loads for each animal type (from Table 4-14) are spread evenly over the land use on a per acre basis. Table 4-15 demonstrates this breakdown by land use.

4.4.3 Pets

The total fecal coliform load from pets in the Holmans Creek watershed can be determined by using the number of pets and the given fecal coliform generation rates for dogs. These data were developed from the 1990 US Census and an estimate of the number of pets per household derived from the number of licensed dogs in Shenandoah County. After the total fecal loads are determined it is necessary to calculate the loads for each land use. In this case, this task simply requires dividing the total load by two, since pets are distributed evenly over only two land uses (mixed urban and farmstead) in the Holmans Creek watershed and do not contribute to direct loads. These fecal coliform loads are presented in Table 4-16.

4.4.4 Confined Broilers and Turkey (Litter Application)

As described in the Source Assessment, confined poultry are in all sub-watersheds. The litter generated by the confined poultry is applied to three land uses: cropland, orchards, and improved pasture/hay. This section describes the approach used for deriving the fecal coliform application rates from confined poultry. The application rates are generated from the total amount of litter generated in each sub-watershed, the application schedule, and the rate of decay of litter during the storage.

First, the total amount of litter applied to the three land uses (cropland, orchards, and improved pasture or hay) within each sub-watershed is calculated. Using information on the existing practices and the acres receiving litter application from the nutrient management plans, the amount of litter applied in Holmans Creek (tons/year) is summarized in Table 4-17.

Using information from Tables 4-17, 4-18 and the existing application practices, the amount of litter applied to each land use on a monthly basis can be determined. Table 4-19

Table 4-15. Total Fecal Coliform Loads from Wildlife by Land Use

Sub-Watershed	Animal	Cropland (counts/ year)	Farmstead (counts/ year)	Forest (counts/ year)	Mixed Urban (counts/ year)	Orchard (counts/ year)	Improved Pasture/Hay (counts/ year)	Unimproved Pasture (counts/ year)	Water (counts/ year)
HC-1	Deer	9.03E+12		4.99E+13		2.98E+12	7.64E+13	5.36E+12	2.93E+12
	Goose	6.95E+07					5.88E+08	4.12E+07	6.99E+08
	Raccoon		6.59E+12	4.06E+13	0.00E+00	2.43E+12			1.01E+12
	Beaver								3.29E+08
	Muskrat			0.00E+00					0.00E+00
	Total	**9.03E+12**	**6.59E+12**	**9.04E+13**	**0.00E+00**	**5.41E+12**	**7.64E+13**	**5.36E+12**	**3.95E+12**
HC-2	Deer	3.92E+12		2.09E+13		2.42E+13	2.10E+13	8.34E+12	1.60E+12
	Goose	4.30E+07					2.30E+08	9.14E+07	3.65E+08
	Raccoon		1.40E+12	1.27E+13	5.40E+11	1.46E+13			5.96E+11
	Beaver								1.86E+08
	Muskrat			1.81E+10					1.63E+11
	Total	**3.92E+12**	**1.40E+12**	**3.36E+13**	**5.40E+11**	**3.88E+13**	**2.10E+13**	**8.34E+12**	**2.36E+12**
HC-3	Deer	2.23E+13		5.26E+13		7.70E+12	7.90E+13	1.74E+13	3.65E+12
	Goose	1.58E+08					5.61E+08	1.23E+08	8.42E+08
	Raccoon		4.47E+12	4.08E+13	1.70E+12	5.97E+12			1.08E+12
	Beaver								2.74E+08
	Muskrat			5.21E+10					4.69E+11
	Total	**2.23E+13**	**4.47E+12**	**9.35E+13**	**1.70E+12**	**1.37E+13**	**7.90E+13**	**1.74E+13**	**5.20E+12**
HC-4	Deer	4.35E+13		9.66E+13		9.44E+12	1.54E+14	6.66E+12	6.33E+12
	Goose	2.95E+08					1.04E+09	4.51E+07	1.38E+09
	Raccoon		5.45E+12	7.71E+13	9.20E+12	7.53E+12			2.03E+12
	Beaver								1.75E+08
	Muskrat			2.36E+10					2.12E+11
	Total	**4.35E+13**	**5.45E+12**	**1.74E+14**	**9.20E+12**	**1.70E+13**	**1.54E+14**	**6.66E+12**	**8.57E+12**
TOTAL		**7.88E+13**	**4.69E+13**	**6.69E+14**	**3.00E+13**	**1.24E+14**	**3.30E+14**	**3.77E+13**	**2.77E+13**

Totals may not equal due to rounding.
See Appendix C for the conversion of the counts/year to counts/month and/or counts/acre/day.

Table 4-16. Total Fecal Coliform Loads from Pets by Land Use

Sub-watershed	Number of Animals	Fecal Coliform Generation Rates (counts/year)	Total Fecal Coliform Load	Total Fecal Coliform Load to Mixed Urban (counts/year)	Total Fecal Coliform Load to Farmstead (counts/year)
HC-1	22	1.64E+11	3.61E+12	0.00E+00	3.61E+12
HC-2	17	1.64E+11	2.79E+12	1.39E+12	1.39E+12
HC-3	38	1.64E+11	6.23E+12	3.12E+12	3.12E+12
HC-4	49	1.64E+11	8.04E+12	4.02E+12	4.02E+12
Total	**126**		**2.07E+13**	**8.53E+12**	**1.21E+13**

HC-1 has no Mixed Urban land use designation
Totals may not equal due to rounding.
See Appendix C for the conversion of the counts/year to counts/acre/day.

Table 4-17. Litter Application to the Different Land Uses in Holmans Creek

Sub-watershed	Land Use	Acres	Percent Receiving Application	Acreage Receiving Litter Application	Litter Applied (tons/acre/year)	Litter Applied (tons/year)
HC-1	Cropland	136	75%	102	6	614
	Orchard	45	60%	27	1	27
	Improved Pasture/Hay	1,155	50%	578	2	1,155
Total		**1,336**		**707**		**1,796**
HC-2	Cropland	84	75%	63	6	377
	Orchard	517	60%	310	1	310
	Improved Pasture/Hay	449	50%	225	2	449
Total		**1,050**		**598**		**1,136**
HC-3	Cropland	345	75%	172	6	1,030
	Orchard	119	60%	71	1	71
	Improved Pasture/Hay	1,222	50%	611	2	1,222
Total		**1,686**		**854**		**2,323**
HC-4	Cropland	664	75%	498	6	2,988
	Orchard	144	60%	86	1	86
	Improved Pasture/Hay	2,348	50%	**1,174**	2	2,348
Total		**3,156**		**1,758**		**5,422**
Total		***7,228***		***3,917***		***10,677***

(Note: litter application based on available acreage, not available litter)
Totals may not equal due to rounding.

Table 4-18. Calculation of Fecal Coliform Content of Litter Generated

Sub-watershed	Total Litter Applied (tons)	% Litter from broilers	% Litter from turkeys	Average Fecal Coliform Load/ton litter (counts/ton/year)	Fecal Coliform Load (counts/year)
HC-1	1,796	37%	63%	6.02E+12	1.08E+16
HC-2	1,137	100%	0%	1.41E+13	1.61E+16
HC-3	2,323	22%	78%	4.21E+12	9.79E+15
HC-4	5,423	66%	34%	9.75E+12	5.29E+16
Total	**10,679**			**3.41E+13**	**8.96E+16**

Totals may not equal due to rounding.

Table 4-19. Monthly Application of Litter

Sub-watershed	Land Use	Litter Applied (tons/year)	Litter Applied Jan.	Litter Applied Feb.	Litter Applied Mar.	Litter Applied Apr.	Litter Applied May	Litter Applied Jun.	Litter Applied Jul.	Litter Applied Aug.	Litter Applied Sep.	Litter Applied Oct.	Litter Applied Nov.	Litter Applied in Dec.
Land Use Receiving Litter			1% P,C	3% P,C	11% C,O,P	20% C,O,P	20% C,O,P	2% P	2% P	5% P	15% P,C	15% C	3% C	3% P,C
HC–1	Cropland	614	–	–	62.71	114.02	114.02	–	–	–	–	269.47	53.89	–
	Orchard	27	–	–	5.84	10.61	10.61	–	–	–	–	–	–	–
	I. Pasture/ Hay	1,155	17.96	53.89	129.06	234.66	234.66	35.93	35.93	89.82	269.47	–	–	53.89
Total		**1,796**	**18**	**54**	**198**	**359**	**359**	**36**	**36**	**90**	**269**	**269**	**54**	**54**
HC–2	Cropland	377	–	–	37.27	67.77	67.77	–	–	–	–	170.57	34.11	–
	Orchard	310	–	–	66.95	121.72	121.72	–	–	–	–	–	–	–
	I. Pasture /Hay	449	11.37	34.11	20.86	37.94	37.94	22.74	22.74	56.86	170.57	–	–	34.11
Total		**1,137**	**11**	**34**	**125**	**227**	**227**	**23**	**23**	**57**	**171**	**171**	**34**	**34**
HC–3	Cropland	1,030	–	–	131.90	239.82	239.82	–	–	–	–	348.43	69.69	–
	Orchard	71	–	–	15.41	28.01	28.01	–	–	–	–	–	–	–
	I. Pasture/ Hay	1,222	23.23	69.69	108.21	196.74	196.74	46.46	46.46	116.14	348.43	–	–	69.69
Total		**2,323**	**23**	**70**	**256**	**465**	**465**	**46**	**46**	**116**	**348**	**348**	**70**	**70**
HC–4	Cropland	2,988	–	–	433.97	789.04	789.04	–	–	–	–	813.42	162.68	–
	Orchard	86	–	–	18.65	33.91	33.91	–	–	–	–	–	–	–
	I. Pasture/ Hay	2,348	54.23	162.68	143.89	261.62	261.62	108.46	108.46	271.14	813.42	–	–	162.68
Total		**5,423**	**54**	**163**	**597**	**1,085**	**1,085**	**108**	**108**	**271**	**813**	**813**	**163**	**163**

Note: With the exception of March, April, and May, land use categories are listed in order of highest priority to lowest priority. Each of the land uses receives equal priority for these three months.

P = Improved Pasture/Hay
C = Cropland,
O = Orchard
– = No application to this land use.
Totals may not equal due to rounding.

presents the monthly application of litter (tons) in each land use of the four sub-watersheds. Litter is applied based on the monthly land use prioritization determined from existing practices within the watershed. The monthly percentage of the total available litter is initially applied to the land use with the highest priority. If this amount of litter is more than that land use is capable of holding, that land use receives its maximum capacity and the remaining litter is applied to the land use with the second highest priority. Land use priorities are displayed in the row entitled Land Use Receiving Litter.

When comparing the litter generated to the litter applied, results show a deficit of 2.5 percent indicating that litter is imported to Holmans Creek. The details and results of the comparison are depicted in Table 4-20.

Table 4-20. Calculation of Amount of Litter Imported

Sub-watershed	Broiler Houses	Broilers	Turkey Houses	Turkeys	Broiler Litter (tons)	Turkey Litter (tons)	Litter Generated in Segment (tons)
HC-1	8	201152	4	61384	1,238	2150	3,388
HC-2	6	150864	0	0	929	0	929
HC-3	2	50288	2	30692	310	1075	1,385
HC-4	20	502880	3	46038	3,096	1612	4,708
Total	**36**	**905,184**	**9**	**138,114**	**5,573**	**4,837**	**10,410**
Totals may not equal due to rounding.						**Litter Generated:**	**10,410**
						Litter Applied:	**10,677**
						Litter Imported:	**267**
							2.5%

The final step is to estimate the fecal coliform content in the litter applied each month to the three different land uses. The fecal coliform content of the litter applied varies each month due to the storage and die off.

The staring point for the litter storage-decay process is in June where all the litter storage bins are empty. Each month 149.7 tons of poultry litter are generated in sub-watershed HC1. The following steps describe the approach used to estimate the fecal coliform content in the manure at the end of each month.

- 149.7 tons of litter are generated and stored during the month of June, which contains an estimated total fecal coliform content of 9.01E+14 (Table 4-19).

- 35.9 tons of litter are applied to improved pasture in June. This represents a 2.16E+14 count of fecal coliform. The remaining litter (113.8 tons) contains 6.85E+14 fecal coliforms. At the end of the month, when accounting for decay during storage, the remaining fecal coliform counts in the pile of litter at the end of the month is 6.22E+13.[1]

- This amount is carried over (stored) during the month of July where additional litter generated during this month is added to the stored litter pile. The same process is repeated, subtracting the amount applied, if any application is scheduled, then applying the monthly decay of fecal coliform to the remaining pile.

Tables 4-21 through 4-24 describe the monthly fecal coliform content of poultry litter, application rates to each land use designation, by sub-watershed respectively.

4.4.5 Confined Dairy Cows

As described in the Source Assessment, there are two dairy farms in the Holmans Creek watershed, both in sub-watershed HC-3. The dairy manure generated by the confined dairy cows is applied to cropland only. This section describes the approach used for deriving the fecal coliform application rates from confined dairy cows. The approach used to derive the total fecal coliform load in applied manure is similar to that used for poultry. Since some of the dairy cows are confined for portions of each day, whereas poultry are constantly confined, confinement rates are factored into the development of fecal coliform application rates for confined dairy cows. The application rates are generated from the total amount of manure generated, the confinement rate, the application schedule, and the rate of decay of manure during the storage.

Based on the number of cows in each dairy farm, the confinement rates and the production of fecal coliform by each animal, the monthly amount of manure produced and fecal coliform loads are calculated. These are presented in Table 4-25.

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[1] The litter decay is assumed to follow a first order decay rate based on the equation:

$C = C_o\ e^{(-kt)}$ where: C is the counts of fecal coliform remaining in the pile after the decay process, C_o is the initial fecal counts in the pile (6.85E+14 for the month) of June, K the fecal coliform decay rate (0.08 day-1) and t is the time in days (30 for the month of June).

$C = 6.85E{+}14 * e^{(-0.08*30)} = 6.22E{+}13$ counts of fecal coliform in the pile at the end of June

Table 4-21. Fecal Coliform Content of Litter in Storage, HC-1

Month	Litter In Storage (tons)	Fecal Coliform in Storage (counts)	Litter Generated (tons)	Fecal Coliform Generated (counts)	Subtotal – litter (tons)	Subtotal – Fecal Coliform (counts)	Litter Applied to Cropland (tons)	Fecal Coliform Applied to Cropland (counts)	Litter Applied to Orchards (tons)	Fecal Coliform Applied to Orchards (counts)	Litter Applied to Improved Pasture/ Hay (tons)	Fecal Coliform Applied to Improved Pasture/ Hay (counts)	Fecal Coliform Remaining (counts)	Fecal Coliform Remaining After Decay (counts)
Jan	239.5	6.57E+13	149.7	9.01E+14	389.2	9.67E+14	0.0	0.00E+00	0.0	0.00E+00	18.0	4.46E+13	9.23E+14	7.73E+13
Feb	371.3	7.73E+13	149.7	9.01E+14	521.0	9.79E+14	0.0	0.00E+00	0.0	0.00E+00	53.9	1.01E+14	8.77E+14	9.16E+13
Mar	467.1	9.16E+13	149.7	9.01E+14	616.8	9.93E+14	62.7	1.01E+14	5.8	9.40E+12	129.1	2.08E+14	6.75E+14	5.65E+13
Apr	419.2	5.65E+13	149.7	9.01E+14	568.9	9.58E+14	114.0	1.92E+14	10.6	1.79E+13	234.7	3.95E+14	3.53E+14	3.20E+13
May	209.6	3.20E+13	149.7	9.01E+14	359.3	9.33E+14	114.0	2.96E+14	10.6	2.76E+13	234.7	6.10E+14	0.00E+00	0.00E+00
Jun	0.0	0.00E+00	149.7	9.01E+14	149.7	9.01E+14	0.0	0.00E+00	0.0	0.00E+00	35.9	2.16E+14	6.85E+14	6.22E+13
Jul	113.8	6.22E+13	149.7	9.01E+14	263.5	9.64E+14	0.0	0.00E+00	0.0	0.00E+00	35.9	1.31E+14	8.32E+14	6.97E+13
Aug	227.6	6.97E+13	149.7	9.01E+14	377.3	9.71E+14	0.0	0.00E+00	0.0	0.00E+00	89.8	2.31E+14	7.40E+14	6.20E+13
Sep	287.4	6.20E+13	149.7	9.01E+14	437.1	9.63E+14	0.0	0.00E+00	0.0	0.00E+00	269.5	5.94E+14	3.70E+14	3.35E+13
Oct	167.7	3.35E+13	149.7	9.01E+14	317.4	9.35E+14	269.5	7.94E+14	0.0	0.00E+00	0.0	0.00E+00	1.41E+14	1.18E+13
Nov	47.9	1.18E+13	149.7	9.01E+14	197.6	9.13E+14	53.9	2.49E+14	0.0	0.00E+00	0.0	0.00E+00	6.64E+14	6.03E+13
Dec	143.7	6.03E+13	149.7	9.01E+14	293.4	9.62E+14	0.0	0.00E+00	0.0	0.00E+00	53.9	1.77E+14	7.85E+14	6.57E+13

Totals may not equal due to rounding.

Table 4-22. Fecal Coliform Content of Litter in Storage, HC-2

Month	Litter In Storage (tons)	Fecal Coliform in Storage (counts)	Litter Generated (tons)	Fecal Coliform Generated (counts)	Subtotal – litter (tons)	Subtotal – Fecal Coliform (counts)	Litter Applied to Cropland (tons)	Fecal Coliform Applied to Cropland (counts)	Litter Applied to Orchards (tons)	Fecal Coliform Applied to Orchards (counts)	Litter Applied to Improved Pasture/ Hay (tons)	Fecal Coliform Applied to Improved Pasture/ Hay (counts)	Fecal Coliform Remaining (counts)	Fecal Coliform Remaining After Decay (counts)
Jan	151.6	9.76E+13	94.8	1.34E+15	246.4	1.44E+15	0.0	0.00E+00	0.0	0.00E+00	11.4	6.63E+13	1.37E+15	1.15E+14
Feb	235.0	1.15E+14	94.8	1.34E+15	329.8	1.45E+15	0.0	0.00E+00	0.0	0.00E+00	34.1	1.50E+14	1.30E+15	1.36E+14
Mar	295.6	1.36E+14	94.8	1.34E+15	390.4	1.47E+15	37.3	1.41E+14	66.9	2.53E+14	20.9	7.88E+13	1.00E+15	8.39E+13
Apr	265.3	8.39E+13	94.8	1.34E+15	360.1	1.42E+15	67.8	2.68E+14	121.7	4.81E+14	37.9	1.50E+14	5.24E+14	4.75E+13
May	132.7	4.75E+13	94.8	1.34E+15	227.4	1.39E+15	67.8	4.13E+14	121.7	7.42E+14	37.9	2.31E+14	-4.69E-01	-3.93E-02
Jun	0.0	0.00E+00	94.8	1.34E+15	94.8	1.34E+15	0.0	0.00E+00	0.0	0.00E+00	22.7	3.21E+14	1.02E+15	9.23E+13
Jul	72.0	9.23E+13	94.8	1.34E+15	166.8	1.43E+15	0.0	0.00E+00	0.0	0.00E+00	22.7	1.95E+14	1.24E+15	1.03E+14
Aug	144.0	1.03E+14	94.8	1.34E+15	238.8	1.44E+15	0.0	0.00E+00	0.0	0.00E+00	56.9	3.43E+14	1.10E+15	9.20E+13
Sep	181.9	9.20E+13	94.8	1.34E+15	276.7	1.43E+15	0.0	0.00E+00	0.0	0.00E+00	170.6	8.82E+14	5.49E+14	4.98E+13
Oct	106.1	4.98E+13	94.8	1.34E+15	200.9	1.39E+15	170.6	1.18E+15	0.0	0.00E+00	0.0	0.00E+00	2.10E+14	1.75E+13
Nov	30.3	1.75E+13	94.8	1.34E+15	125.1	1.36E+15	34.1	3.70E+14	0.0	0.00E+00	0.0	0.00E+00	9.86E+14	8.95E+13
Dec	91.0	8.95E+13	94.8	1.34E+15	185.7	1.43E+15	0.0	0.00E+00	0.0	0.00E+00	34.1	2.62E+14	1.17E+15	9.76E+13

Totals may not equal due to rounding.

Table 4-23. Fecal Coliform Content of Litter in Storage, HC-3

Month	Litter In Storage (tons)	Fecal Coliform in Storage (counts)	Litter Generated (tons)	Fecal Coliform Generated (counts)	Subtotal – litter (tons)	Subtotal – Fecal Coliform (counts)	Litter Applied to Cropland (tons)	Fecal Coliform Applied to Cropland (counts)	Litter Applied to Orchards (tons)	Fecal Coliform Applied to Orchards (counts)	Litter Applied to Improved Pasture/ Hay (tons)	Fecal Coliform Applied to Improved Pasture/ Hay (counts)	Fecal Coliform Remaining (counts)	Fecal Coliform Remaining After Decay counts)
Jan	309.7	5.95E+13	193.6	8.16E+14	503.3	8.75E+14	0.0	0.00E+00	0.0	0.00E+00	23.2	4.04E+13	8.35E+14	6.99E+13
Feb	480.1	6.99E+13	193.6	8.16E+14	673.6	8.86E+14	0.0	0.00E+00	0.0	0.00E+00	69.7	9.16E+13	7.94E+14	8.29E+13
Mar	603.9	8.29E+13	193.6	8.16E+14	797.5	8.99E+14	131.9	1.49E+14	15.4	1.74E+13	108.2	1.22E+14	6.11E+14	5.11E+13
Apr	542.0	5.11E+13	193.6	8.16E+14	735.6	8.67E+14	239.8	2.83E+14	28.0	3.30E+13	196.7	2.32E+14	3.19E+14	2.90E+13
May	271.0	2.90E+13	193.6	8.16E+14	464.6	8.45E+14	239.8	4.36E+14	28.0	5.09E+13	196.7	3.58E+14	0.00E+00	0.00E+00
Jun	0.0	0.00E+00	193.6	8.16E+14	193.6	8.16E+14	0.0	0.00E+00	0.0	0.00E+00	46.5	1.96E+14	6.20E+14	5.62E+13
Jul	147.1	5.62E+13	193.6	8.16E+14	340.7	8.72E+14	0.0	0.00E+00	0.0	0.00E+00	46.5	1.19E+14	7.53E+14	6.31E+13
Aug	294.2	6.31E+13	193.6	8.16E+14	487.8	8.79E+14	0.0	0.00E+00	0.0	0.00E+00	116.1	2.09E+14	6.70E+14	5.61E+13
Sep	371.7	5.61E+13	193.6	8.16E+14	565.2	8.72E+14	0.0	0.00E+00	0.0	0.00E+00	348.4	5.37E+14	3.34E+14	3.03E+13
Oct	216.8	3.03E+13	193.6	8.16E+14	410.4	8.46E+14	348.4	7.18E+14	0.0	0.00E+00	0.0	0.00E+00	1.28E+14	1.07E+13
Nov	61.9	1.07E+13	193.6	8.16E+14	255.5	8.26E+14	69.7	2.25E+14	0.0	0.00E+00	0.0	0.00E+00	6.01E+14	5.45E+13
Dec	185.8	5.45E+13	193.6	8.16E+14	379.4	8.70E+14	0.0	0.00E+00	0.0	0.00E+00	69.7	1.60E+14	7.10E+14	5.95E+13

Totals may not equal due to rounding.

Table 4-24. Fecal Coliform Content of Litter in Storage, HC-4

Month	Litter In Storage (tons)	Fecal Coliform in Storage (counts)	Litter Generated (tons)	Fecal Coliform Generated (counts)	Subtotal – litter (tons)	Subtotal – Fecal Coliform (counts)	Litter Applied to Cropland (tons)	Fecal Coliform Applied to Cropland (counts)	Litter Applied to Orchards (tons)	Fecal Coliform Applied to Orchards (counts)	Litter Applied to Improved Pasture/ Hay (tons)	Fecal Coliform Applied to Improved Pasture/ Hay (counts)	Fecal Coliform Remaining (counts)	Fecal Coliform Remaining After Decay (counts)
Jan	723.0	3.21E+14	451.9	4.41E+15	1174.9	4.73E+15	0.0	0.00E+00	0.0	0.00E+00	54.2	2.18E+14	4.51E+15	3.78E+14
Feb	1120.7	3.78E+14	451.9	4.41E+15	1572.6	4.78E+15	0.0	0.00E+00	0.0	0.00E+00	162.7	4.95E+14	4.29E+15	4.48E+14
Mar	1409.9	4.48E+14	451.9	4.41E+15	1861.8	4.85E+15	434.0	1.13E+15	18.6	4.86E+13	143.9	3.75E+14	3.30E+15	2.76E+14
Apr	1265.3	2.76E+14	451.9	4.41E+15	1717.2	4.68E+15	789.0	2.15E+15	33.9	9.25E+13	261.6	7.14E+14	1.73E+15	1.57E+14
May	632.7	1.57E+14	451.9	4.41E+15	1084.6	4.56E+15	789.0	3.32E+15	33.9	1.43E+14	261.6	1.10E+15	0.00E+00	0.00E+00
Jun	0.0	0.00E+00	451.9	4.41E+15	451.9	4.41E+15	0.0	0.00E+00	0.0	0.00E+00	108.5	1.06E+15	3.35E+15	3.04E+14
Jul	343.4	3.04E+14	451.9	4.41E+15	795.3	4.71E+15	0.0	0.00E+00	0.0	0.00E+00	108.5	6.42E+14	4.07E+15	3.41E+14
Aug	686.9	3.41E+14	451.9	4.41E+15	1138.8	4.75E+15	0.0	0.00E+00	0.0	0.00E+00	271.1	1.13E+15	3.62E+15	3.03E+14
Sep	867.7	3.03E+14	451.9	4.41E+15	1319.6	4.71E+15	0.0	0.00E+00	0.0	0.00E+00	813.4	2.90E+15	1.81E+15	1.64E+14
Oct	506.1	1.64E+14	451.9	4.41E+15	958.0	4.57E+15	813.4	3.88E+15	0.0	0.00E+00	0.0	0.00E+00	6.90E+14	5.78E+13
Nov	144.6	5.78E+13	451.9	4.41E+15	596.5	4.47E+15	162.7	1.22E+15	0.0	0.00E+00	0.0	0.00E+00	3.25E+15	2.95E+14
Dec	433.8	2.95E+14	451.9	4.41E+15	885.7	4.70E+15	0.0	0.00E+00	0.0	0.00E+00	162.7	8.64E+14	3.84E+15	3.21E+14

Totals may not equal due to rounding.

Table 4-27. Total Fecal Coliform Loads from Confined Dairy

Month	Dairy 1		Dairy 2		Manure Generated/ Day/Cow (kgal)	Fecal Coliform (counts/day/ cow)	Days/ Month	Monthly Fecal Coliform Load (counts)
	Number of Dairy Cows	Confinement Rates	Number of Dairy Cows	Confinement Rates				
Jan	66	75%	125	100%	0.02	5.40E+09	31	2.92E+13
Feb	66	75%	125	100%	0.02	5.40E+09	28	2.66E+13
Mar	66	75%	125	100%	0.02	5.40E+09	31	2.92E+13
Apr	66	60%	125	100%	0.02	5.40E+09	30	2.67E+13
May	66	50%	125	100%	0.02	5.40E+09	31	2.65E+13
Jun	66	50%	125	100%	0.02	5.40E+09	30	2.56E+13
Jul	66	50%	125	100%	0.02	5.40E+09	31	2.65E+13
Aug	66	50%	125	100%	0.02	5.40E+09	31	2.65E+13
Sep	66	50%	125	100%	0.02	5.40E+09	30	2.56E+13
Oct	66	50%	125	100%	0.02	5.40E+09	31	2.65E+13
Nov	66	60%	125	100%	0.02	5.40E+09	30	2.67E+13
Dec	66	75%	125	100%	0.02	5.40E+09	31	2.92E+13
Total								**3.25E+14**

Totals may not equal due to rounding.

Based on the total amount of manure applied, existing practices and the monthly application schedule from nutrient management plans, the total number of acres receiving manure and monthly application rates (Kgal/Month) can be determined. Since dairy manure is applied to cropland only, all 1,044 Kgal are applied to 345 acres of cropland in sub-watershed HC-3. Table 4-26 presents the monthly application rate in 1,000 gallons of dairy manure.

Table 4-26. Monthly Application of Manure

Sub-watershed	Land Use	Total Manure Applied (Kgal)	Manure Applied by Month (Kgal)											
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
HC-3	Cropland	1,044	–	31	209	282	104	–	–	31	157	125	104	–

– = no application that month.

The final step is to estimate the fecal coliform content in the dairy manure applied each month. The fecal coliform content varies each month due to the storage and die off. A similar approach to the one used for the poultry litter die off is used to account for the die-off during storage and estimate the fecal coliform content at the end of each month. The monthly fecal coliform application rates are depicted in Table 4-27.

Table 4-27. Fecal Coliform Content of Manure in Storage, HC-3

Month	Manure In Storage (kgal)	Fecal Coliform in Storage (counts)	Manure Generated (kgal)	Fecal Coliform Generated (counts)	Subtotal – Manure (kgal)	Subtotal – Fecal Coliform (counts)	Manure Applied to Cropland (kgal)	Fecal Coliform Applied to Cropland (counts)	Fecal Coliform Remaining (counts)	Fecal Coliform Remaining After Decay (counts)
Jan	191.5	2.61E+08	87.0	2.92E+13	278.5	2.92E+13	0.0	0.00E+00	2.92E+13	2.61E+08
Feb	278.5	2.61E+08	87.0	2.66E+13	365.5	2.66E+13	31.3	2.28E+12	2.43E+13	6.10E+08
Mar	334.2	6.10E+08	87.0	2.92E+13	421.2	2.92E+13	208.9	1.45E+13	1.47E+13	1.32E+08
Apr	212.4	1.32E+08	87.0	2.67E+13	299.4	2.67E+13	282.0	2.51E+13	1.55E+12	2.02E+07
May	17.4	2.02E+07	87.0	2.64E+13	104.4	2.64E+13	104.4	2.64E+13	0.00E+00	0.00E+00
Jun	0.0	0.00E+00	87.0	2.56E+13	87.0	2.56E+13	0.0	0.00E+00	2.56E+13	3.33E+08
Jul	87.0	3.33E+08	87.0	2.64E+13	174.1	2.64E+13	0.0	0.00E+00	2.64E+13	2.36E+08
Aug	174.1	2.36E+08	87.0	2.64E+13	261.1	2.64E+13	31.3	3.17E+12	2.33E+13	2.08E+08
Sep	229.8	2.08E+08	87.0	2.56E+13	316.8	2.56E+13	156.7	1.27E+13	1.29E+13	1.68E+08
Oct	160.1	1.68E+08	87.0	2.64E+13	247.2	2.64E+13	125.3	1.34E+13	1.30E+13	1.17E+08
Nov	121.8	1.17E+08	87.0	2.67E+13	208.9	2.67E+13	104.4	1.33E+13	1.33E+13	1.73E+08
Dec	104.4	1.73E+08	87.0	2.92E+13	191.5	2.92E+13	0.0	0.00E+00	2.92E+13	2.61E+08

Totals may not equal due to rounding.

4.4.6 Unconfined Dairy Cows

It was determined that there are 40 unconfined dairy cows that have access to streams and that 10 percent of the manure generated while these cows are in the vicinity of the stream is directly deposited into the stream. These values, along with the estimated number of hours spent in the vicinity of the stream and the monthly rates of fecal coliform generation for dairy cows (determined from Table 4-27), were used to determine the total amount of fecal coliform generated by unconfined dairy cows. These values are presented in Table 4-28.

Table 4-28. Total Fecal Coliform Loads from Unconfined Dairy

Month	Dairy Cows in Dairy 1	Percentage of Time Unconfined, Dairy 1	Manure Generated (kgal/day/cow)	Fecal Coliform (counts/day/ cow)	Days/ Month	Monthly Fecal Coliform Load (counts)
Jan	66	25%	0.02	5.40E+09	31	2.76E+12
Feb	66	25%	0.02	5.40E+09	28	2.52E+12
Mar	66	25%	0.02	5.40E+09	31	2.76E+12
Apr	66	40%	0.02	5.40E+09	30	4.28E+12
May	66	50%	0.02	5.40E+09	31	5.52E+12
Jun	66	50%	0.02	5.40E+09	30	5.35E+12
Jul	66	50%	0.02	5.40E+09	31	5.52E+12
Aug	66	50%	0.02	5.40E+09	31	5.52E+12
Sept	66	50%	0.02	5.40E+09	30	5.35E+12
Oct	66	50%	0.02	5.40E+09	31	5.52E+12
Nov	66	40%	0.02	5.40E+09	30	4.28E+12
Dec	66	25%	0.02	5.40E+09	31	2.76E+12

Totals may not equal due to rounding.

All manure produced by unconfined dairy cows that is not directly deposited to water is applied to unimproved pasture. The fecal coliform load to unimproved pasture by unconfined dairy cows was calculated based on the total fecal coliform load generated, stream access rates, time spent in the vicinity of the stream and direct deposition rates. Table 4-29 summarizes these fecal coliform deposition totals.

4.4.7 Unconfined Beef Cattle

The first step to determining the total fecal coliform loads from beef cattle is calculating the monthly fecal coliform counts. The total animal numbers and fecal coliform generation rates for beef cattle are used to do this. These values are presented in Table 4-30.

Table 4-29. Calculation of Unconfined Dairy Deposition in Stream and to Unimproved Pasture

Month	Number of Dairy Cows with Access to Streams	Fecal Coliform Deposition Directly to Stream	Hours Spent in Vicinity of Stream	Unconfined Dairy Fecal Coliform Generation (counts/month/ cow)	Unconfined Dairy Fecal Coliform In Stream (counts)	Unconfined Dairy Fecal Coliform On Unimproved Pasture (counts)
Jan.	40	10%	0.5	4.18E+10	3.45E+09	2.76E+12
Feb.	40	10%	0.5	3.82E+10	3.15E+09	2.51E+12
Mar.	40	10%	1	4.18E+10	6.91E+09	2.76E+12
Apr.	40	10%	1.5	6.48E+10	1.60E+10	4.26E+12
May	40	10%	1.5	8.36E+10	2.07E+10	5.50E+12
Jun.	40	10%	2	8.11E+10	2.67E+10	5.32E+12
Jul.	40	10%	2	8.36E+10	2.76E+10	5.50E+12
Aug.	40	10%	2	8.36E+10	2.76E+10	5.50E+12
Sep.	40	10%	1.5	8.11E+10	2.00E+10	5.33E+12
Oct.	40	10%	1	8.36E+10	1.38E+10	5.51E+12
Nov.	40	10%	1	6.48E+10	1.07E+10	4.27E+12
Dec.	40	10%	0.5	4.18E+10	3.45E+09	2.76E+12

*Totals may not equal due to rounding.

Table 4-30. Total Fecal Coliform Loads from Beef Cattle

Sub-watershed	Number of Beef Cattle	Fecal Coliform Generated by Beef Cattle (counts/day)	Fecal Coliform Load Generated by Beef Cattle counts/month)
HC-1	280	5.40E+09	4.60E+13
HC-2	346	5.40E+09	5.69E+12
HC-3	854	5.40E+09	1.40E+14
HC-4	430	5.40E+09	7.07E+13
Total	**1910**		**2.62E+14**

Totals may not equal due to rounding.

Similar to unconfined dairy cows, 60 percent of all beef cattle have access to streams and 10 percent of the manure generated while these cattle are in the vicinity of the stream is directly deposited into the water. These estimates, along with the number of hours spent in the vicinity of the stream and the monthly rates of fecal coliform generation for beef cattle (from Table 4-30), were used to determine the total amount of fecal coliform deposited in the water. All manure produced by unconfined beef cattle that is not directly deposited to water is deposited on both improved and unimproved pasture. Table 4-31 summarizes both direct and indirect fecal coliform deposition totals from beef cattle. To determine the total fecal coliform loads to each of these land uses, the indirect deposition totals to each sub-watershed, presented in Table 4-31, were divided evenly over the two land uses. This calculation is based on the assumption that beef cattle spend equal amounts of time on each of these land uses. These indirect deposition values are presented in Table 4-32.

4.5 Existing Scenario Conditions

The water quality calibration runs were performed using the existing condition scenario. The intent of this scenario is to reproduce the long-term average fecal coliform fate and transport in the watershed. The simulation period selected for the calibration is from 1994 to 1998. During this period, best management practices (BMPs) were implemented and need to be reflected in the existing condition scenario. As determined by the USGS, 1999 was not considered a representative hydrologic year due to extremely low stream flow values in the Chesapeake Bay region. As a result, 1999 was not included in the simulation period due to its tendency to skew the overall simulation values by producing extremely high simulated fecal coliform concentrations. These high values can be attributed to the direct source loads (e.g., cattle, septic, wildlife) during extended periods of extreme low stream flow.

4.5.1 BMPs in Holmans Creek

The TMDL process requires the identification of previously BMPs in the Holmans Creek watershed. This information was obtained from the nutrient management plans for farms in the watershed, information provided by the HCWC, and DCR. These sources identified information regarding 22 farms (poultry, dairy, and beef cattle) located within the watershed.

The approximate acreage, designated land uses, and appropriate BMPs (runoff reduction, direct application reduction) were used in conjunction with general reduction efficiencies, obtained from the EPA's Chesapeake Bay Program (USEPA 2000), to determine the BMP efficiencies in Holmans Creek. The percent reduction efficiency for total suspended solids was used as a surrogate for fecal coliforms. This surrogate was chosen to represent the BMPs physical and particle removal characteristics and because the biological die off rates are applied in the model.

Table 4-31. Calculation of Direct and Indirect Fecal Coliform Deposition by Unconfined Beef Cattle

Month	Access to Streams (%)	Deposited in Streams (%)	Hours spent in vicinity of stream	Total Fecal Coliform Load HC-1 (counts)	Total Fecal Coliform Load HC-2 (counts)	Total Fecal Coliform Load HC-3 (counts)	Total Fecal Coliform Load HC-4 (counts)	Total Direct Deposition HC-1 (counts)	Total Direct Deposition HC-2 (counts)	Total Direct Deposition HC-3 (counts)	Total Direct Deposition HC-4 (counts)	Total Indirect Deposition HC-1 (counts)	Total Indirect Deposition HC-2 (counts)	Total Indirect Deposition HC-3 (counts)	Total Indirect Deposition HC-4 (counts)
Jan	60%	10%	1	4.60E+13	5.69E+13	1.40E+14	7.07E+13	1.15E+11	1.42E+11	3.51E+11	1.77E+11	4.59E+13	5.67E+13	1.40E+14	7.05E+13
Feb	60%	10%	1	4.60E+13	5.69E+13	1.40E+14	7.07E+13	1.15E+11	1.42E+11	3.51E+11	1.77E+11	4.59E+13	5.67E+13	1.40E+14	7.05E+13
Mar	60%	10%	1.5	4.60E+13	5.69E+13	1.40E+14	7.07E+13	1.73E+11	2.13E+11	5.26E+11	2.65E+11	4.58E+13	5.67E+13	1.40E+14	7.04E+13
Apr	60%	10%	2	4.60E+13	5.69E+13	1.40E+14	7.07E+13	2.30E+11	2.84E+11	7.02E+11	3.53E+11	4.58E+13	5.66E+13	1.40E+14	7.03E+13
May	60%	10%	2	4.60E+13	5.69E+13	1.40E+14	7.07E+13	2.30E+11	2.84E+11	7.02E+11	3.53E+11	4.58E+13	5.66E+13	1.40E+14	7.03E+13
Jun	60%	10%	2.5	4.60E+13	5.69E+13	1.40E+14	7.07E+13	2.88E+11	3.55E+11	8.77E+11	4.42E+11	4.57E+13	5.65E+13	1.39E+14	7.02E+13
Jul	60%	10%	2.5	4.60E+13	5.69E+13	1.40E+14	7.07E+13	2.88E+11	3.55E+11	8.77E+11	4.42E+11	4.57E+13	5.65E+13	1.39E+14	7.02E+13
Aug	60%	10%	2.5	4.60E+13	5.69E+13	1.40E+14	7.07E+13	2.88E+11	3.55E+11	8.77E+11	4.42E+11	4.57E+13	5.65E+13	1.39E+14	7.02E+13
Sep	60%	10%	2	4.60E+13	5.69E+13	1.40E+14	7.07E+13	2.30E+11	2.84E+11	7.02E+11	3.53E+11	4.58E+13	5.66E+13	1.40E+14	7.03E+13
Oct	60%	10%	1.5	4.60E+13	5.69E+13	1.40E+14	7.07E+13	1.73E+11	2.13E+11	5.26E+11	2.65E+11	4.58E+13	5.67E+13	1.40E+14	7.04E+13
Nov	60%	10%	1.5	4.60E+13	5.69E+13	1.40E+14	7.07E+13	1.73E+11	2.13E+11	5.26E+11	2.65E+11	4.58E+13	5.67E+13	1.40E+14	7.04E+13
Dec	60%	10%	1	4.60E+13	5.69E+13	1.40E+14	7.07E+13	1.15E+11	1.42E+11	3.51E+11	1.77E+11	4.59E+13	5.67E+13	1.40E+14	7.05E+13

*Totals may not equal due to rounding.

Table 4-32. Indirect Fecal Coliform Deposition by Unconfined Beef Cattle

Month	Fecal Coliform Deposited to Improved Pasture/Hay HC-1 (counts)	Fecal Coliform Deposited to Improved Pasture/Hay HC-2 (counts)	Fecal Coliform Deposited to Improved Pasture/Hay HC-3 (counts)	Fecal Coliform Deposited to Improved Pasture/Hay HC-4 (counts)	Fecal Coliform Deposited to Unimproved Pasture HC-1 (counts)	Fecal Coliform Deposited to Unimproved Pasture HC-2 (counts)	Fecal Coliform Deposited to Unimproved Pasture HC-3 (counts)	Fecal Coliform Deposited to Unimproved Pasture HC-4 (counts)
Jan	2.28E+13	2.82E+13	6.97E+13	3.51E+13	2.28E+13	2.82E+13	6.97E+13	3.51E+13
Feb	2.28E+13	2.82E+13	6.97E+13	3.51E+13	2.28E+13	2.82E+13	6.97E+13	3.51E+13
Mar	2.28E+13	2.81E+13	6.94E+13	3.49E+13	2.28E+13	2.81E+13	6.94E+13	3.49E+13
Apr	2.27E+13	2.80E+13	6.91E+13	3.48E+13	2.27E+13	2.80E+13	6.91E+13	3.48E+13
May	2.27E+13	2.80E+13	6.91E+13	3.48E+13	2.27E+13	2.80E+13	6.91E+13	3.48E+13
Jun	2.26E+13	2.79E+13	6.89E+13	3.47E+13	2.26E+13	2.79E+13	6.89E+13	3.47E+13
Jul	2.26E+13	2.79E+13	6.89E+13	3.47E+13	2.26E+13	2.79E+13	6.89E+13	3.47E+13
Aug	2.26E+13	2.79E+13	6.89E+13	3.47E+13	2.26E+13	2.79E+13	6.89E+13	3.47E+13
Sep	2.27E+13	2.80E+13	6.91E+13	3.48E+13	2.27E+13	2.80E+13	6.91E+13	3.48E+13
Oct	2.28E+13	2.81E+13	6.94E+13	3.49E+13	2.28E+13	2.81E+13	6.94E+13	3.49E+13
Nov	2.28E+13	2.81E+13	6.94E+13	3.49E+13	2.28E+13	2.81E+13	6.94E+13	3.49E+13
Dec	2.28E+13	2.82E+13	6.97E+13	3.51E+13	2.28E+13	2.82E+13	6.97E+13	3.51E+13

*Totals may not equal due to rounding.

BMP data were collected from the Holmans Creek Watershed Coordinator (Arner, personal communication, 2001) and DCRs 319 Grant Cost Share Database (Cottle, 2000). These data were combined and compared to identify BMPs implemented in the watershed. Instances where BMPs were identified but not implemented resulted in those BMPs being removed from consideration. The compiled data identified BMPs installed since 1995. The BMPs were identified by land use, sub-watershed, and total affected acreage to estimate potential reductions in fecal coliform loading.

BMPs that provide an improvement in the overall agricultural operation, such as covered manure or litter storage facilities, are incorporated in the model by exclusion of incidental runoff. These BMPs reduce runoff of manure and fecal coliform from storage facilities during wet weather events. The specific land applications and die off rates previously described were not adjusted, and limiting indirect application to planned events reflects the BMPs contribution to fecal coliform runoff reduction. BMP reductions for stream fencing and stream crossing structures estimates were applied to the model by reducing the number of livestock with stream access as previously described.

BMPs affecting pastures (i.e., alternative watering systems, filter strips, pasture land management) were categorized by sub-watershed. The ratio of the BMP acreage to the land use acreage was determined. This ratio when multiplied by the percent reduction efficiency of the BMP provided a potential reduction to fecal coliform loading. For example, 45 acres of improved pasture and hay land use BMPs were identified in sub-watershed HC-1. The percent of the total acreage was multiplied by the removal efficiency, the resulting percent reduction was applied to the indirect fecal coliform loads on improved pasture and hay land use to account for BMP reduction in fecal coliform wash off to the stream. This procedure was used for each BMP, land use and sub-watershed. Table 4-33 provides a brief summary of the BMP implementation data used within Holmans Creek watershed.

Table 4-33. BMP Implementation Data

Sub-Watershed	Land Use	BMP Implemented	Acreage Applied	Reduction Efficiency
HC-1	Improved Pasture	Watering systems	90	51
	Improved Pasture	Stream crossing structure	90	14
	Hay	Filter strips	45	53
	Improved Pasture	Filter strips	45	53
	Hay	Woodland buffer	45	70
	Improved Pasture	Woodland buffer	45	70
HC-2	Improved Pasture	Watering systems	200	51
	Improved Pasture	Pastureland management	200	14
HC-3	Improved Pasture	Watering systems	874	51
	Improved Pasture	Pastureland management	390	14
	Improved Pasture	Stream crossing structure	390	14
	Hay	Overseeding	16	53
	Improved Pasture	Overseeding	16	53
	Improved Pasture	Expand dairy loafing lot	28	14
HC-4	Hay	Overseeding	146	53
	Improved Pasture	Overseeding	146	53
	Improved Pasture	Watering system	628	51
	Hay	Filter strips	56	53
	Improved Pasture	Filter strips	56	53
	Improved Pasture	Stream crossing structure	112	14
	Improved Pasture	Sun shading	112	14
	Improved Pasture	Pastureland management	90	14

4.5.2 Water Quality Parameters

Several variables in the water quality model affect the simulation of the amount of fecal coliform washed off the land and transported through the Holmans Creek sub-watersheds. Table 4-34 summarizes the final water quality calibration parameters for the Holmans Creek watershed. The most important variables are discussed, in detail, following the summary table.

Table 4-34. Final Calibration Values for RCHRES and GQUAL Inputs

Parameter	Definition	Units	Final HSPF Values Used for Holmans Creek	HSPF Default Values	HSPF Range of Values	
					Min.	Max.
KS	The weighing factor for hydraulic routing	none	0.5	0.0	0	0.99
FSTDEC	First-order decay rate for QUAL	day^{-1}	2.5	None	0.00001	None
THFST	Temperature correction coefficient for first-order decay of QUAL	none	1.17	1.07	1.0	2.0
IOQC	FC Concentration in Interflow	$counts/ft^3$	1,400	0	0	None
AOQC	FC Concentration in Groundwater	$counts/ft^3$	1,400	0	0	None
WQSOP	Rate of Surface runoff	in/hour	2.15	1.64	0.01	None

Decay Rate on Soil

An important variable needed in the PQAL section is the decay rate on the soil. This parameter is indirectly reflected in the HSPF input file through the variable SQOLIM. SQOLIM is the maximum accumulation rate. The decay rate is computed as the ratio of accumulation rate of fecal coliform (monthly ACQOP values) divided by the maximum accumulation rate (SQOLIM). The model allows input of monthly values for ACQOP and SQOLIM allowing for the use of seasonal decay rates. The decay rates range from 0.2 to 0.4 percent/day (Novotny, 1994). A value of 0.4 day^{-1} was used for all the simulations and was not varied during the calibration. The variation of the decay rate was not very sensitive to the simulated fecal coliform loads from all the land uses.

Rate of Surface Runoff That Removes 90 Percent of Stored Fecal Coliform Per Hour

One of the key parameters in the PQAL section that drives the amount of fecal coliform washed off the land is the rate of surface runoff that will remove 90 percent of stored fecal coliform per hour (WSQOP). WSQOP measures the susceptibility of the fecal coliform to wash off and adjusting it will change the fecal coliform peak concentrations during storm event. In fact, WSQOP is the most sensitive variable for reproducing peak wash off loads and consequently fecal coliform NPS loads. This value was varied during the calibration to match observed range of fecal coliform concentrations. In fact, the intent of the water quality calibration is to reproduce as best as possible the ranges of fecal coliform observed concentrations. The final value used for the calibration is 2.15 inches per hour.

Concentration of Fecal Coliform in the Interflow (IOQC) and Groundwater Flow (AOQC)

The PQAL section also requires input of the concentration of fecal coliform in the interflow (MON-IFLW-CONC - IOQC) and groundwater flow (MON-GRND-CONC - AOQC). A study conducted by the USGS on agriculture and bacterial groundwater quality in southeastern West Virginia, found that a karst aquifer in a pasture impacted watershed had a fecal coliform density of less than 10 cfu/100 ml. (Boyer, undated). Additional data is provided from a well testing program completed in the Lower Dry River watershed in Rockingham County (Shenandoah Valley SWCD, 1994). Lower Dry River is an agricultural watershed that has similar land uses and hydrology to that of Holmans Creek. Based on a data set containing 100 wells, the reported mean value is 5 counts/100 ml. This value is used in the water quality simulations for both the IOQC and AOQC values (1,400 counts/ ft^3 which corresponds to a concentration of 5 counts/100 ml - The HSPF model requires units as counts/ft^3 for these two values).

Changes to these two variables were not sensitive to the total simulated annual average fecal coliform loadings in Holmans Creek. However, stream fecal coliform concentrations will be sensitive to the variations of these values (IOQC and AOQC) during critical summer flow. In fact, the simulated flow distribution indicates on the average most of the flow is coming from the interflow and groundwater (21% of the flow is from surface runoff, 29 percent is from interflow, and 50 percent is from groundwater flow). Consequently, the use of reliable observed well data is important to reproduce the fecal coliform loadings during summer low flow in Holmans Creek.

First Order In-stream Decay Rate of Fecal Coliform

The transport of fecal coliform in model reaches uses the GQAL section of the RCHRES module. The key input parameter for the GQAL section is first order in-stream decay of fecal coliform. The values used in the calibration are the high end published range of one to five and one half/day (Thomann, 1987). A value of 2.5 day^{-1} was used for all the calibration runs. This variable was not sensitive to the final simulated fecal coliform concentrations in the stream.

4.5.3 Results of the Water Quality Calibration

This section presents the analysis of the calibration results and discusses the main fecal coliform component loads in Holmans Creek. The calibrated model runs identify the major sources and their potential impact on the development of allocation scenarios. The model was run for the representative period from 1994 to 1998. Figure 4-8 shows the results of the final water quality calibration run. It indicates a good agreement between observed and simulated values during low and high flow conditions. The main objective of the calibration runs was to get the best fit possible between simulated fecal coliform values and the range of observed simulated fecal coliform data.

The main objective of the calibration runs was to get the best fit possible between simulated fecal coliform values and the range of observed and simulated fecal coliform data. In fact when calibrating integrated watershed models such as HSPF, the objective is not to match exactly each simulated and observed observation, but to make sure that the long term simulated water quality response captures the range of observed values which better describes and reproduces the response in the watershed.

One of the main reasons is that water quality observations are usually instantaneous measurements (taken at a specific time during the day) where as simulated values are daily averages calculated by the model using hourly-simulated output. This is shown in Figure 4.8 where some of the observed-instantaneous fecal coliform values are higher than the simulated values.

Further assessment of the calibration accuracy can be done by summarizing the model simulated fecal coliform output by source. In fact, the additional fecal typing data, which was discussed in Section 3.5.3, can be used to compare the simulated and observed overall simulated fecal coliform contribution from each source.

The fecal coliform typing observations used to track concurrently the four main sources in Holmans Creek indicate that 41, 25, 22, and 10 percent are from human, wildlife, cattle, and poultry respectively (Wiggins, 2001). The fecal typing data also suggests that the fecal coliform loadings from poultry are not a major contribution. The fecal typing data captures the fecal coliform load distribution mainly during low-flow events where non-point source loadings are not the dominant source.

The results of the annual average (1994-1998) simulated loadings for both the direct and indirect sources are presented in Table 4-35.

Table 4-35 indicates that the dominant long-term average source of fecal coliform loads to Holmans Creek is from poultry litter. The long-term-average over the 5-year simulation period indicates that poultry litter contributes 83 percent of the fecal loads to Holmans Creek, especially during storms and high runoff events. This percentage varies from year to year and from season to season. It is also important to note that fecal coliform loads from poultry are associated with increased surface water volume. The increased volume and surface water flow contribute to a less concentrated fecal coliform load and do not usually occur during critical low flow periods. During the critical low-flow period it is expected that the main sources to Holmans Creek are from direct and continuous loads such as failing septic systems, wildlife, and livestock.

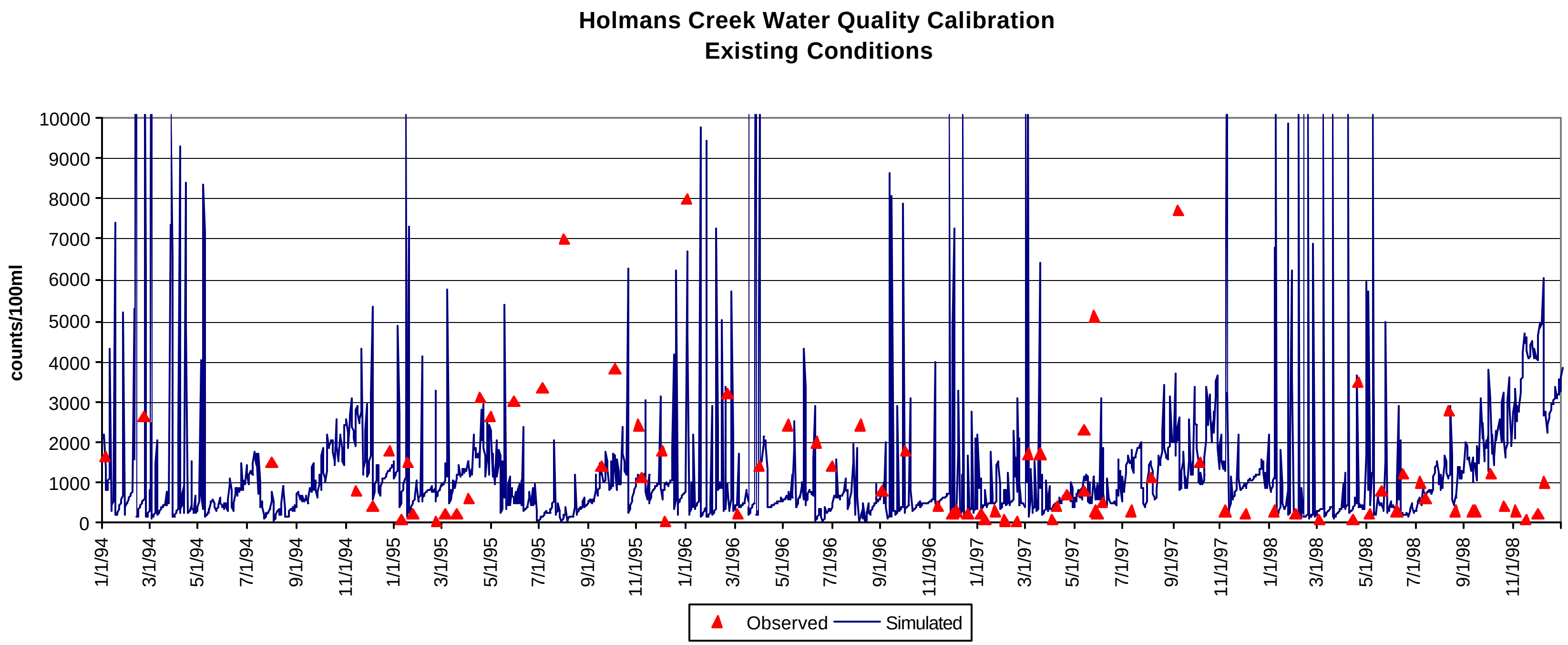

Figure 4-8. Simulated and Observed Fecal Coliform Concentrations of the Water Quality Calibration

Table 4-35. Distribution of Simulated Annual Average Loads to the Stream (1994-1998)

	HC1	HC2	HC3	HC4	Total	% of Total
Indirect Sources						
Poultry	1.62E+14	1.92E+14	2.4E+14	5.81E+14	1.17E+15	82.12%
Beef Cattle Indirect	1.88E+13	3.86E+13	5.94E+13	2.24E+13	1.39E+14	9.76%
Dairy Cows Indirect	–	–	2.18E+12	–	2.18E+12	0.15%
Wildlife Indirect	4.95+12	8.00E+12	9.40E+12	9.904E+12	3.23E+13	2.27%
Pets Indirect	–	7.20E+10	1.48E+11	2.16E+11	4.37E+11	0.03%
Direct Sources						
Septic Direct	7.54E+11	6.00E+12	1.33E+13	1.72E+13	4.41E+13	3.10%
Wildlife Direct	3.95E+12	2.36E+12	5.20E+12	8.57E+12	2.01E+13	1.41%
Beef Cattle	2.42E+12	2.99E+12	7.37E+12	3.71E+12	1.65E+13	1.16%
Dairy Cows	–	–	1.80E+11	–	1.80E+11	0.01%

In order to assess the calibration results, simulated loads where summarized just for the period from June to December 1998. This period was selected since it represents the highest frequency of violations of the 30-day geometric mean. In addition, this period is more representative of the time where the fecal typing data was collected. Table 4-36 depicts fecal loads contribution from each source.

Table 4-36. Distribution of Simulated Loads from June -December 1998

	Simulated Loads June –December 1998 (%)	Observed Fecal Typing Source Contribution (%)
Poultry	3.4	10
Septic Direct	52.7	42
Wildlife *	23.9	25
Cattle *	20.1	23

* includes both direct and indirect loads

Table 4-36 clearly indicates that the water quality calibration captures well the existing fecal coliform observed loadings distribution. In fact, the simulated fecal coliform loadings agree with the observed loads using the fecal typing technique.

4.5.4 Sensitivity Analysis

After a reasonable calibration is achieved, sensitivity analysis is performed to have a better understanding of the model response to variations in one or several key input variables. Results from the water quality calibration section indicated that the dominant and critical fecal coliform loads to the stream are from failing septic system, wildlife deposition, and beef cattle deposition. Consequently, the objective of the sensitivity analysis runs is to assess and analyze the model response to changes in these loads. Such sensitivity runs will help give a better understanding of the water quality response in the watershed and will also help in the development of the TMDL allocation scenarios. The distribution of the fecal coliform direct loads to the stream indicates that 50 percent of the total loads are from failing septic systems. The distribution of the direct loads also shows that these loads are approximately double the loads from wildlife. Using the calibrated water quality input file, the following sensitivity analysis runs were performed:

- ***Sensitivity Analysis Run 1***—Water quality response to septic loads only (all the other sources including non-point sources were turned off)
- ***Sensitivity Analysis Run 2***—Water quality response when the septic loads are doubled (all the other sources including non-point sources were turned off)
- ***Sensitivity Analysis Run 3***—Water quality response when the septic loads are cut by half (all the other sources including non-point sources were turned off)

The sensitivity analysis runs were processed using the 30-day geometric fecal coliform as an indicator of the model response. Figure 4-9 depicts the results of the model sensitivity analysis.

The primary indication from these runs is that the loads from only the failing septic systems causes numerous violation to the 30-day geometric mean standard. In fact, the standard is violated 65 percent of the time under this run (sensitivity run 1). Run 2 of the sensitivity analysis, doubling the septic loads with all the other sources turned off, shows similar widespread violations where the geometric mean is exceeded 96 percent of the time. Results from the sensitivity run 3 (half of the septic loads and all the other sources turned off) still indicate violations of the standard, which is exceeded 39 percent of the time.

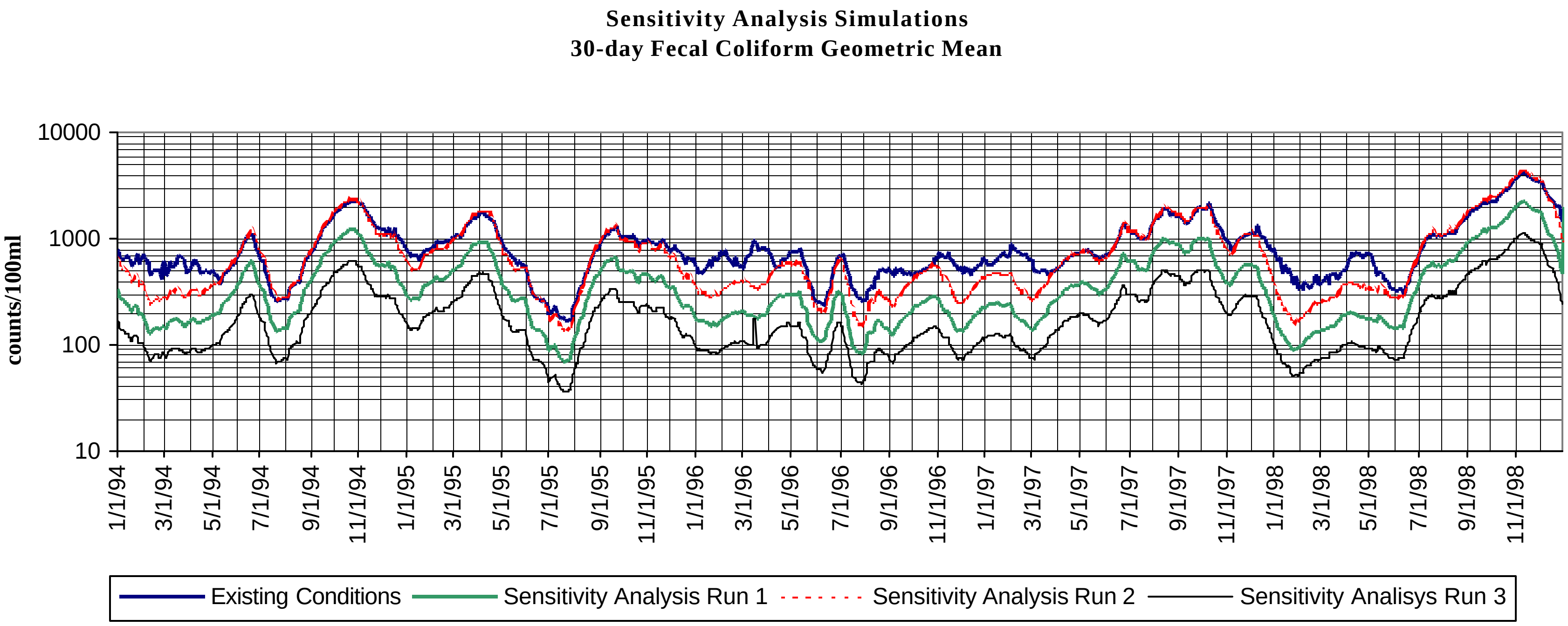

Figure 4-9. Sensitivity Analysis Runs

The results of the sensitivity run 3 give also an indication of the impact of the wildlife loads only with all the other sources turned off. In fact, half of the septic loads (2.20E+13 counts/year) are equivalent to the full direct deposition from wildlife (2.0E+13). Consequently, the model response to half of the septic loads (run 3) is comparable to the model response to the full loads from wildlife. Thus, the results from sensitivity run 3 clearly indicate that controlling all the sources due to human activities will not be sufficient to meet the state water quality standard. This key result will be used as a guide to develop the model allocation scenarios.

5. Load Allocations

5.1 Background

The objective of a TMDL plan is to allocate allowable loads among the various pollutant sources so that the appropriate control actions can be taken to achieve water quality standards. The specific objective of the TMDL plan in Holmans Creek is to determine the required reductions in fecal coliform loadings from point (direct) and non-point sources in order to meet state water quality standards. The state water quality standard for fecal coliform used in the TMDL development is the 30-day geometric mean of 200 counts/100 ml. The incorporation of the different sources into the TMDL is defined in the following equation (USEPA, 1999):

$$TMDL = WLA + LA + MOS$$

Where:

WLA	=	waste load allocation (point sources)
LA	=	load allocation (non-point sources)
MOS	=	margin of safety

The margin of safety (MOS) is included in the TMDL development process to account for any uncertainty on loadings and the fate of fecal coliforms in Holmans Creek. There are two basic approaches for incorporating the MOS (USEPA, 1999):

- The MOS is implicitly incorporated using conservative model assumptions to develop allocations or
- The MOS is explicitly specified as a portion of the total TMDL and the remainder is used for the allocations.

The allocation scenario for Holmans Creek was designed to meet the water quality standard of a geometric mean of 200 counts/100 ml. An MOS of 5 percent was incorporated explicitly in the TMDL equation by reducing the target fecal coliform concentration from 200 counts/100 ml to 190 counts/100 ml. In other words, the simulated concentrations were compared to a target of a geometric mean (of 30 data points) of 190 counts/100 ml. The time period selected for the load allocation covers the same period used in the water quality calibration (January 1994 to December 1998) and it includes both high and low flow conditions.

5.2 Existing Conditions

The results of the simulation for the existing conditions were presented in Section 5.5.3. Using the entire simulation period from 1994 to 1998 indicated that indirect deposition from poultry litter is the dominant source of fecal coliform to the stream. However, the analysis of the in-stream geometric mean violations indicated that the critical time in the stream is during low flow conditions where the dominant sources are direct fecal coliform deposition from failing septic systems, wildlife and cattle. In fact, fecal coliform loadings from the direct sources affect water quality during the low flow conditions causing a persistent violation. On the other hand, non-point source contributions are of small duration and associated with higher runoff volume resulting in much greater dilution.

5.3 Allocations Scenarios

The TMDL development requires that the level of reduction from each pollutant in a watershed be determined in order to meet the applicable water quality standard. The TMDL comprises the sum of individual waste load allocations (WLAs) for point sources and load allocations (LAS) for non-point sources.

5.3.1 Wasteload Allocations

There are five VPDES permits, issued by the DEQ, that allow discharge of fecal coliform to Holmans Creek. The four privately owned permits are located in HC-1 and HC-2. Under a general Permit VAG40 these residences may discharge less than or equal to 1,000 gallons/day with a fecal coliform discharge limitation of 200 counts/100 ml. A VPDES permit has also been issued to Bowman Agricultural Enterprises, LLC for a future discharge. When the planned sewage treatment plant becomes operational, it will be subject to a monthly geometric mean fecal coliform limit of 200 counts/100 ml. The design flow for this facility is 0.0075 MGD. Because this facility is not yet operational, the wasteload allocation of fecal coliform is equal to the permit limit as a conservative assumption supporting the MOS. The future point source load is negligible in its impact on instream fecal coliform levels. Table 5-1 shows the permitted load, allocated load, and percent reduction of point sources in Holmans Creek.

Table 5-1. Wasteload Allocations to Point Sources in Holmans Creek

Point Source	Future Load	Allocated Load	Percent Reduction
Permitted Sources	8.7×10^{7} counts/day	8.7×10^{7} counts/day	0

5.3.2 Load Allocations

Several load allocation scenarios were evaluated to meet the TMDL goal of a 30-day geometric mean of 190 counts/100 ml. Scenario 1 assesses the fecal coliform contribution of wildlife alone to Holmans Creek. The objective of this initial scenario is to assess the possibility to develop a TMDL allocation plan that meets state water quality standards only by reducing sources of fecal coliform caused by human activities and agricultural operations. Consequently, in this scenario contributions from all fecal coliform sources, other than those deposited directly in the stream by wildlife, were turned off in the model. Figure 5-1 compares the estimated load in the existing condition and allocation scenario 1. Scenario 1 indicates that the fecal coliform due to wildlife causes concentrations in the stream to violate the 30-day geometric mean 38 percent of the time. This scenario indicates that eliminating load allocations of fecal coliform caused by human activities will not provide a TMDL that meets the Virginia water quality standards.

Scenario 2 assesses the impact of reducing completely the direct sources from human activities (septic and beef cattle) and a 50 % reduction in wildlife direct loads. Under scenario 2 the NPS loads were not reduced. Under scenario 2 the 30-day geometric mean is exceeded 27 percent of the time indicating that further load reductions are needed.

Scenario 3 uses the same direct load reductions used in Scenario 2 (100% septic, 100% beef cattle, and 50% wildlife) and a reduction of 75% in the NPS loads. Table 5-2 indicates that additional NPS load reductions have little or no effect on the 30-day fecal coliform geometric mean when compared to scenario 2. In fact, under scenario 3 the 30-day geometric mean is exceeded 26 percent of the time compared to 27 % under scenario 2.

Existing Conditions and Implementation Scenario 1
Wildlife Source Only - 100% Reduction of All Other Sources

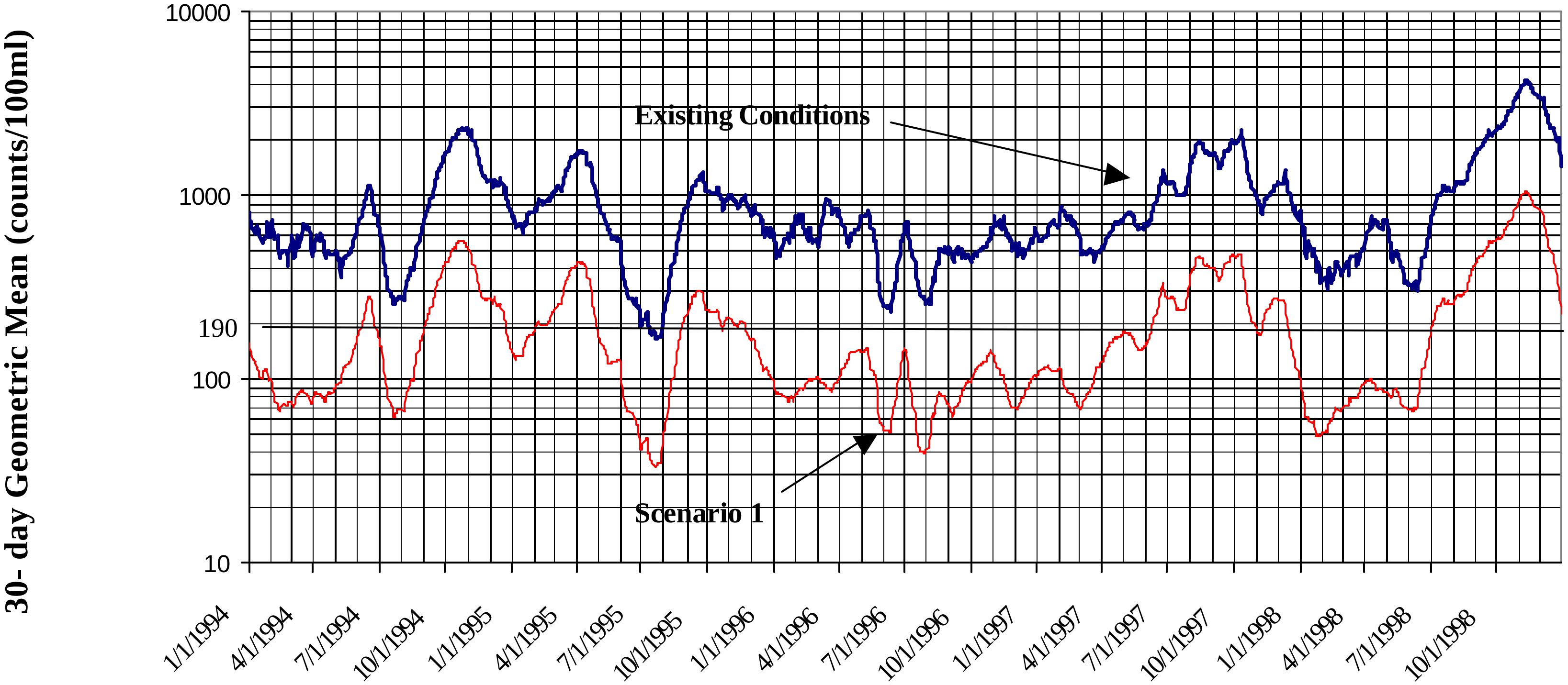

Figure 5-1. 30-Day Geometric Mean from Wildlife Contribution Only (Existing Conditions and Scenario 1)

Scenario 4 assess the impact of reducing further the direct wildlife load to 75% with a 100% reduction in the septic and beef cattle loads. Under this scenario the NPS load reductions are set at 25% and the percent violation of the 30-day geometric mean is 6 percent.

Based on the results of allocation scenarios 1, 2, 3, and 4, all allocation scenarios should include complete elimination of fecal coliform loadings from human sources and direct deposition from cattle and additional source reductions. In addition, these scenarios indicate that various reduction of NPS loads is not sensitive to the 30-day geometric mean. Simulation scenarios were then conducted to identify the required reduction in wildlife loadings that will result in an allocation plan that meets the state water quality standards. The TMDL scenarios and results are summarized in Table 5-2.

Table 5-2. Existing Conditions and TMDL Allocation Scenarios for Holmans Creek

Scenario	Reduction in Loadings from Existing Conditions (%)				% days Geometric Mean > than 190 counts/100ml
	Direct Wildlife	Failing Septic	Direct Cattle	NPS	
Existing Conditions	0	0	0	0	99
1	0	100	100	100	38
2	50	100	100	0	27
3	50	100	100	75	26
4	75	100	100	25	6
5	90	100	100	0	0
6	0	100	100	25	63

Only Scenario 5 meets the TMDL allocation requirement of no violation of the 190 counts/100 ml geometric mean. Under Scenario 5, the instantaneous standard of 1,000 counts/100 ml is exceeded 9.5 percent of the time. Fecal coliform concentrations resulting from Scenario 5 are presented in Figure 5-2. Under scenario 5, no reduction in non-point sources of fecal coliform is required (Table 5-3). Scenario 5 requires a 100 percent reduction of direct source loadings from humans and cattle as well as a 90 percent reduction from wildlife. Table 5-4 presents the direct loads reductions for the TMDL implementation scenario (scenario 5). An additional scenario (6) was developed to evaluate possible phased implementation plans. This scenario does not reduce direct wildlife fecal coliform contributions and meets the instantaneous standard 90 percent of days modeled.

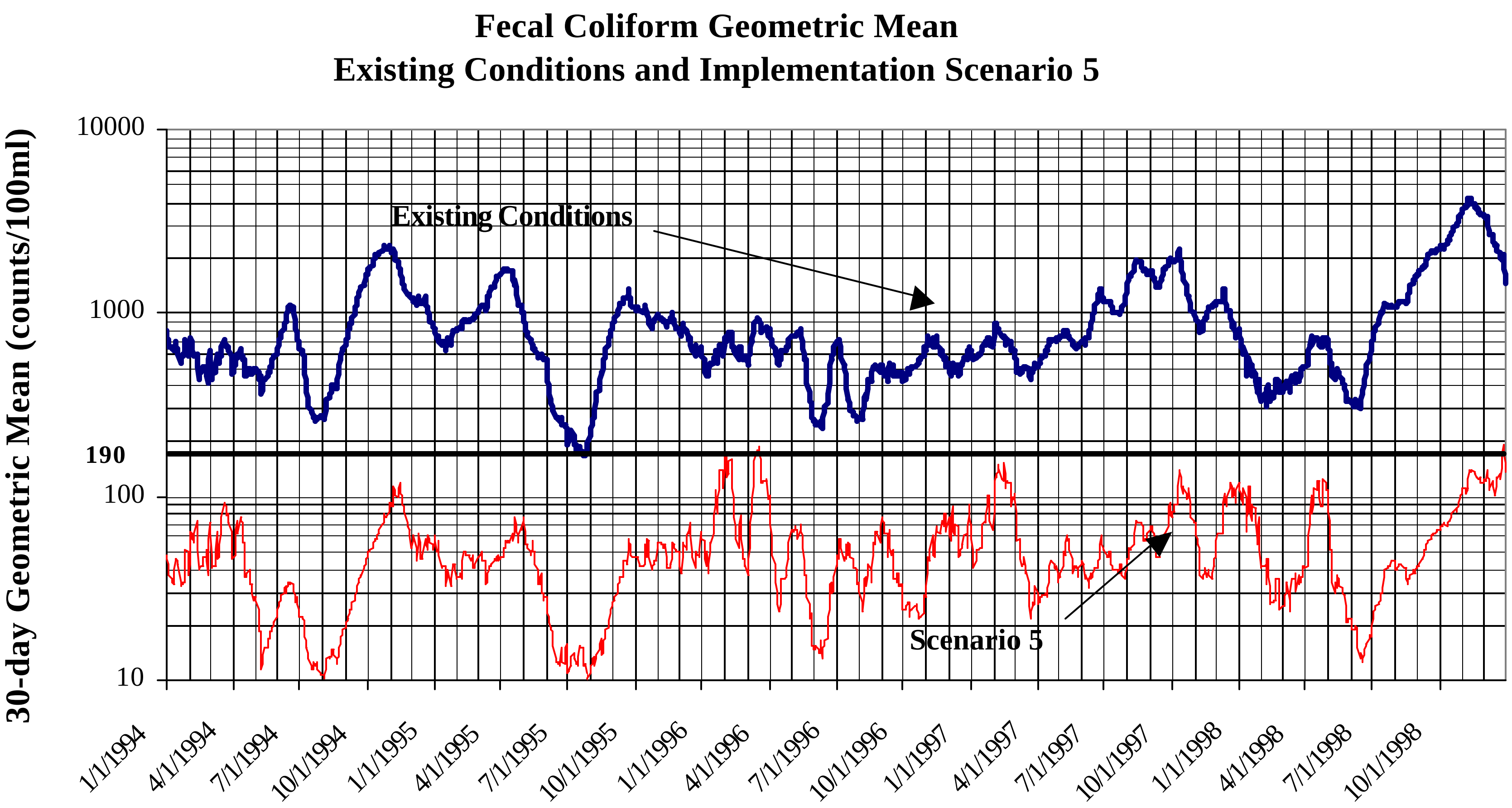

Figure 5-2. 30-Day Geometric Mean - Existing Conditions and Scenario 5

Table 5-2. Annual Non-point Source Loads from Holmans Creek Under Existing Conditions and Corresponding Reductions for TMDL Allocation Scenario 5

Land-Use Category/ Source	Existing Conditions		Allocation Scenario	
	Existing load (10^{12} Counts)	Percent of Total Load to Stream from Nonpoint Source	TMDL Nonpoint Source Allocation load (10^{12} Counts)	Percent Reduction from Existing Load
Forest	1.2	0.1	1.2	0.0
Cropland	86.4	6.4	86.4	0.0
Orchard	125.0	9.3	125.0	0.0
Pasture 1	993.0	73.5	993.0	0.0
Urban	1.3	0.1	1.3	0.0
Pasture 2	143.0	10.6	143.0	0.0
Farmstead	1.3	0.1	1.3	0.0
Total	**1351.2**	**100.0**	**1351.2**	0.0

Totals may not equal due to rounding.

Table 5-3. Annual NPS Direct Loads from Holmans Creek Under Existing Conditions and Corresponding Reductions for TMDL Allocation Scenario 5

Land-Use Category/ Source	Existing Conditions		Allocation Scenario	
	Existing load (10^{12} Counts)	Percent of total load to stream from direct source	TMDL direct Source Allocation Load (10^{12} Counts)	Percent Reduction from Existing Load
Septic	44.1	54.5	0.0	100.0
Wildlife	20.1	24.9	2.0	90.0
Beef Cattle/Dairy Cows	16.7	20.6	0	100.0
Total	**80.9**	**100.0**	**2.2**	**97.0**

Totals may not equal due to rounding.

5.4 Future Growth

Future growth was considered in development of the TMDL. Changes in human or livestock populations could change point and nonpoint source fecal coliform loads.

Point source wasteload allocations included the future operation of the single industrial sewage treatment plant in Holmans Creek. Although only seasonal operation of the facility is anticipated, a conservative assumption of continued operation was incorporated into the model. The wasteload allocation for this point source are based on the permitted flow and fecal coliform concentration of 200 counts/100 ml. Additionally, operators of the facility are evaluating zero discharge options (Bankson, personal communication, 1999).

The number of households and human population in the watershed was extrapolated from changes in USGS topographic maps and 1990 census, respectively to account for future growth. Because Holmans Creek is not sewered, all new housing was anticipated to use septic systems. Although, new housing is not anticipated to increase loads from failing septic systems for a number of years, failing septics systems and straight pipes, privies or inadequate household sewage treatment was incorporated into the model and allocation scenarios using a 30 percent failure rate for all houses. Using this methodology the modeling assumption accounts for the possible failure of aging septic systems in the future.

Livestock populations were also compared to previous years. Poultry populations were estimated by the number of existing and new poultry houses from USGS maps and confirmed by local sources (Bankson, Bauhan , and Maupin, personal communication, 2000). Other livestock populations in the watershed have been stable or decreasing in recent years and are assumed to remain stable.

Comparison of loads from land use show reduced loads from improved pastures, farmsteads and urban categories. Additionally, the implementation of agricultural best management practices and an active watershed committee have shown a trend in water quality improvement since 1997.

The assumptions used in the model to develop estimates of fecal coliform loads are conservative and provide for a reasonable assurance that the estimated loads account for changes in the land use and populations in the Holmans Creek watershed.

5.5 Summary of TMDL Allocation Scenarios in Holmans Creek

A TMDL for fecal coliform has been developed for Holmans Creek and addresses the following issues.

- The TMDL meets the water quality standard based on the 30-day geometric mean, which explicitly incorporates a margin of safety of 5 percent. After the plan is fully implemented, the 30-day geometric mean will not exceed 190 counts/100 ml.

- The TMDL accounts for all fecal coliform sources (human, agricultural activities, and wildlife).

- A continuous simulation model that applies to high- and low-flow conditions was used. Consequently, both conditions were considered when developing the TMDL.

- Seasonal variations were explicitly included in the modeling approach for this TMDL. The use of a continuous simulation model explicitly incorporates the seasonal variations of rainfall pattern, simulated runoff, and fecal coliform washoff from the land surfaces. In addition, fecal coliform accumulation rates for each land use were developed on a monthly basis. The monthly accumulation rates accounted for the temporal variation in activities within the watershed, including seasonal application of agricultural waste and grazing schedules of livestock.

- The TMDL allocation plan that met the 30-day geometric mean water quality target of 190 counts/100 ml requires a 100% reduction of fecal coliform from failing septic systems, a 100% reduction of direct source loadings from cattle, and a 90% reduction of fecal coliform directly deposited in the stream from wildlife. The summary of fecal coliform TMDL for Holmans Creek is presented in Table 5-5.

Table 5-5. Annual Fecal Coliform Loadings (counts/year) Used for Developing the Fecal Coliform TMDL for Holmans Creek

Parameter	WLA	LA	MOS*	TMDL
Fecal coliform	0.032×10^{12}	$1,353 \times 10^{12}$	68×10^{12}	$1,421 \times 10^{12}$

* Five percent of the TMDL

6. Implementation and Public Participation

6.1 Follow-Up Monitoring

The existing monitoring station located in Holmans Creek will be maintained by VADEQ during the TMDL implementation process. The station 1BHMN002.09 was established in July 1991. VADEQ and VADCR will continue to use this monitoring station for evaluating reductions in fecal coliform counts and the effectiveness of the TMDL in attainment of water quality standards.

Monthly sampling for fecal coliform bacteria will continue at 1BHMN002.09 until the violation rate of Virginia's instantaneous standard, 1,000 counts/100 mL, is reduced to no more than 10%. After this reduction in the fecal coliform violation rate is verified, the monitoring frequency for this parameter will be increased to two are more samples within a 30-day period. This sampling frequency will verify whether or not Virginia's geometric mean standard, 200 counts/100 mL, is met.

6.2 TMDL Implementation Process

The goal of this TMDL is to establish a path that will lead to an expeditious attainment of water quality standards. The first step in this process was to develop a TMDL that can be achieved with reasonable assurance. The second step is to develop a TMDL implementation plan, and the final step is to implement the TMDL.

Section 303(d) of the Clean Water Act and EPA's 303(d) regulation do not provide new implementing mechanisms for TMDLs. However, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act directs VADEQ to develop a plan for the expeditious implementation of TMDLs.

VADEQ plans to incorporate TMDL and TMDL implementation plans as part of the 303(e) Water Quality Management Plans (WQMP). In response to the recent EPA/VADEQ Memorandum of Understanding, VADEQ submitted a Continuous Planning Process to EPA in which Virginia commits to updating the WQMPs, which will be the repository of TMDLs and the implementation plans. Each implementation plan will contain a reasonable assurance section that will detail the availability of funds for implementation of voluntary actions.

One potential source of funding for TMDL implementation is Section 319 of the Clean Water Act. In response to the federal Clean Water Action Plan, Virginia developed a Unified Watershed Assessment that identifies watershed priorities. Watershed restoration activities, such as TMDL implementation, within these priority watersheds are eligible for Section 319 funding. Increases in Section 319 funding in future years will be targeted towards TMDL implementation and watershed restoration.

Watershed stakeholders will have opportunities to provide input and participate in development of the implementation plan, with support from regional and local offices of VADEQ, VADCR and other participating assistance agencies. For example, current regulations of the Virginia Department of Health require correction of all straight pipes and failed septic systems, and it is recommended that all such sources be brought into compliance.

Implementation of best management practices (BMPs) in the watersheds will occur in phases. The benefit of phased implementation is that as stream monitoring continues to occur, accurate measurements of progress being achieved will be recorded. This approach provides a measure of quality control, given the uncertainties that exist in the developed TMDL model. The target for the first phase of implementation will be no more than 10% violation of the 1,000 counts/100 ml instantaneous standard.

Using the model developed to represent existing conditions, an allocation scenario was developed that would result in no more than 10% violation of the 1,000 count/100 ml instantaneous standard. For the Phase I allocation, the model was run for the representative hydrologic period.

6.3 Phase 1 Implementation Scenario

The goal of the Phase I Allocation Scenario was to determine the fecal coliform loading reductions required to reduce to reduce violations of the instantaneous 1,000 counts/100 mL water quality standard to no more than 10 percent.

Implementation of best management practices (BMPs) in the watersheds will continue in stages. The benefit of staged implementation is that it provides a mechanism for developing public support and for evaluating the adequacy of the TMDL in achieving the water quality standard. The Phase I Allocation developed for Holmans Creek requires a 100% reduction of uncontrolled residential discharges, a 100% reduction in livestock direct deposition to the stream, and a 25% reduction in agricultural nonpoint sources (Table 6-1).

Table 6-1. Annual Non-point Source Loads from Holmans Creek Under Existing Conditions and Corresponding Reductions for TMDL Phase 1 Implementation

Land-Use Category/ Source	Existing Conditions		Allocation Scenario	
	Existing Load (10^{12} Counts)	Percent of Total Load to Stream From Nonpoint Source	TMDL Nonpoint Source Allocation load (10^{12} Counts)	Percent Reduction From Existing Load
Forest	1.2	0.1	1.2	0
Cropland	86.4	6.4	64.8	25
Orchard	125.0	9.3	93.8	25
Pasture 1	993.0	73.5	744.8	25
Urban	1.3	0.1	1.3	0
Pasture 2	143.0	10.6	107.3	25
Farmstead	1.3	0.1	1.0	25
Total	**1351**	**100**	**1014**	25

Totals may not equal due to rounding.

Table 6-2. Annual NPS Direct Loads from Holmans Creek Under Existing Conditions and Corresponding Reductions for Phase I Allocation Scenario

Land-Use Category/ Source	Existing Conditions		Allocation Scenario	
	Existing Load (10^{12} Counts)	Percent of Total Load to Stream from Direct Source	TMDL Direct Source Allocation Load (10^{12} Counts)	Percent Reduction from Existing Load
Septic	44.1	54.5	0.0	100.0
Wildlife	20.1	24.9	20.1	0.0
Beef Cattle/Dairy Cows	16.7	20.6	0.0	100.0
Total	**80.9**	**100.0**	**20.1**	**97.0**

Totals may not equal due to rounding.

6.4 Wildlife Contribution

VADEQ and VADCR have developed fecal coliform TMDLs for a number of impaired waters in the State. In some of the streams, as is the case for Holmans Creek, fecal coliform bacteria counts contributed by wildlife result in standards violations, particularly during base flow conditions. Wildlife densities obtained from the Department of Game and Inland Fisheries and analysis or “typing” of the fecal coliform bacteria show that the high densities of muskrat, beaver, and waterfowl are responsible for the elevated fecal bacteria counts in these streams. The following sections discuss the current water quality standard, TMDL allocations, and options to address wildlife fecal coliform contributions.

6.4.1 Designated Uses

All waters in the Commonwealth have been designated as "primary contact" for the swimming use regardless of size, depth, location, water quality or actual use. The fecal coliform bacteria standard is described in 9 VAC 25-260-170 and on page 1-4 in Section 1 of this report. This standard is to be met during all stream flow levels and was established to protect bathers from ingestion of potentially harmful bacteria. However, many headwater streams are small and shallow during base flow conditions when surface runoff has minimal influence on stream flow. Even in pools, these shallow streams do not allow full body immersion during periods of base flow. In larger streams, lack of public access often precludes the swimming use.

Base flow conditions of a stream occur at a higher frequency than flow conditions influenced by precipitation runoff events. As a result, the vast majority of the water quality sampling in the watershed used to determine the impairment occurred during base flow conditions. Therefore, a critical period for modeling to insure the attainment of water quality standards is during base flow conditions with little or no storm runoff.

In the TMDL public participation process, the residents in these watersheds often report that " people do not swim in this stream.” It is obvious that many streams within the state are not used for recreational purposes. In many cases, insufficient depth of the streams along with other physical factors and lack of public accessibility do not provide suitable conditions for swimming or primary contact recreation.

6.4.2 TMDL Allocations

The wildlife contributions of fecal bacteria from muskrats, beavers, and waterfowl are at their highest counts during base flow conditions when there is little or no pollutant wash-off from the adjacent land areas. Therefore, base flow events represent the critical condition because the allocations needed to attain water quality standards during these flow regimes insure that standards were met in all other flow ranges.

For many of these streams, even the removal of all of the sources of fecal coliform (other than wildlife) does not allow the stream to attain standards during these critical conditions (or low flows). TMDL allocation reductions of this magnitude are not realistic and do not meet EPA's guidance for reasonable assurance. Based on the water quality modeling, many of these streams will not be able to attain standards without some reduction in wildlife. **Virginia and EPA are not proposing the elimination of wildlife to allow for the attainment of water quality standards.** This is obviously an impractical action. Clearly, the reduction of wildlife or changing a natural background condition is not the intended goal of a TMDL or any other federal and state water quality management programs.

6.4.3 Options for Resolution of Wildlife Issue

To address the wildlife problem, EPA and Virginia have developed a TMDL strategy that will provide the reasonable assurance necessary under EPA guidance. The first step in this strategy is to develop a phased approach for the attainment of water quality standards in the TMDL. The first phase is to select an interim reduction goal, such as the Stage I implementation target described below. This goal has been presented to the stakeholders in the watershed and is provided here for EPA's approval as part of the TMDL process. In the interim goal or target, the pollutant reductions contained in the allocation were made only on controllable sources identified in the TMDL, setting aside any reduction of wildlife. During the first implementation phase, all reductions from controllable sources called for in the TMDL allocation would be reduced to their appropriate levels. The first phase would be a labor-intensive process that could occur on an incremental basis. While the first phase is underway, Virginia would be working concurrently on the second phase to address the wildlife issue.

Following completion of the first phase reductions, the VADEQ would re-assess the streams to determine if water quality standards had been attained. This effort will also determine if the modeling assumptions and approaches are correct. If it were found that water quality standards are not met, the second phase allocations would be initiated at a level necessary to meet existing standards. In some cases, the effort may never have to go to the second phase.

The second phase of the TMDL will result in the attainment of water quality standards. This phase involves a number of components outlined below:

- EPA has recommended that all States adopt an *E. coli* or enterococci standard for freshwater and enterococci criteria for marine waters by 2003. EPA is pursuing the States' adoption of these standards because there is a stronger correlation between the concentration of these organisms *(E. coli* and enterococci) and the incidence of gastrointestinal illness than with fecal coliform. *E-coli* and enterococci are both bacteriological organisms that can be found in the intestinal tract of warm-blooded animals. Like fecal coliform bacteria, these organisms indicate the presence of fecal contamination. The adoption of the *E. coli* and enterococci standard is scheduled for 2002 in Virginia.

- Recognizing that all waters in the Commonwealth are not used extensively for swimming, VA is considering re-designation of the swimming use for secondary contact due to natural contamination by wildlife, stream size, accessibility to children and widespread social-economic impacts resulting from the cost of improving a stream to a "swimmable" status.

  The re-designation of the current swimming use may require the completion of a use attainability analysis. A Use Attainability Analysis (UAA), is a structured scientific assessment of the factors affecting the attainment of the use which may include physical, chemical, biological, and economic factors as described in the Federal Regulations. The stakeholders in the watershed, Virginia, and EPA will have an opportunity to comment on these special studies.

- Most states apply their water quality standards only to flows above a statistical low flow frequency that is defined as a 7-day average occurring once every 10 years (7Q10). However Virginia's fecal coliform bacteria standard is applied to all flows. Some headwater streams have very minimal flow during periods of low precipitation or droughts. During such low flow events, the counts of fecal coliform bacteria deposited directly into the stream are concentrated because the small flow is unable to dilute the deposition of wastes. In order to attain standards during low flow conditions, it is necessary to reduce the amount of waste deposited directly to the stream. Sources of these wastes include cattle in-stream, wildlife in-stream, septic systems, and wastes conveyed directly to the stream from milking parlors. By applying the standard only to flows greater than 7Q10, the TMDL would not need to insure the attainment of standards during extreme drought flow conditions when stream flow falls below 7Q10.

- Another option that EPA allows for the states is to adopt site-specific criteria based on natural background levels of fecal coliforms. The State must demonstrate that the source of fecal contamination is natural and uncontrollable by effluent limitations and BMPs.

6.5 Public Participation

The development of the Holmans Creek TMDL would not have been possible with out public participation. The Holmans Creek Watershed Committee has been active in organizing stakeholder involvement, assisting citizens to develop an understanding the water quality issues facing the community, and taking steps to address these issues. Coordinating volunteers, initiating water quality monitoring, and seeking out funding to implement BMPs were actions taken by the HCWC. Three public meetings were held in addition to numerous Holmans Creek Watershed Committee meetings.

The first public meeting was held in Forestville on April 12, 2000 to discuss the water quality data and development of the TMDL, about 25 people attended. Copies of the presentation materials and diagrams outlining the development of the TMDL were available for public distribution. The meeting was public noticed in the *Virginia Register*. The North Fork Shenandoah River/Holmans Creek Citizens' Watershed Committee mailed flyers announcing the meeting to residents in the watershed. There was a 30 day-public comment period and no written public comments were received.

The second public meeting was held in New Market on July 27, 2000 to discuss the source assessment input data for the TMDL, about 20 people attended. Copies of the presentation materials from the meeting were available for public distribution. The meeting was public noticed in the *Virginia Register*. The North River Shenandoah River/Holmans Creek Citizens' Watershed Committee mailed flyers announcing the meeting to residents in the watershed. There was a 30 day-public comment period and no public comments were received.

The third public meeting was held in New Market Town Hall in New Market on July 31, 2001 to discuss the draft TMDL, about 21 people attended. Copies of the draft TMDL were available for public distribution. The meeting was public noticed in the *Virginia Register* on July 16, 2001. The public comment period ended on August 15, 2001.

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APPENDIX A

(Fecal Coliform Sampling Summary Data)

Sampling data was obtained from all five sampling locations discussed in this report. Samples were taken at the four Holmans Creek sampling stations (HCWC) over a 5-year period (December 1994 through December), while samples were taken at the VADEQ station from December 1991 through November 1998. These data were compiled and analyzed on a both a seasonal and station basis for fecal coliform concentrations and frequency of standard violation. The figures presented in Appendix A provide a summary of the sampling data. Figures A-1 through A-4 present fecal coliform concentrations for each of the HCWC sampling stations and FigureA-5 provides this same information for the VADEQ sampling station. FigureA-6 provides an overall summary of the mean fecal coliform concentrations for all five stations. Figures A-7 through A-10 present fecal coliform concentrations for each of the four designated seasons (see Section 2.5.2 of the Watershed Characterization) and FigureA-11 summarizes the fecal coliform concentrations for all of the seasons. The frequency of violation of the instantaneous and geometric mean standards for each station and season are presented in FigureA-12 and FigureA-13, respectively. FigureA-14 provides the frequency of violation of the instantaneous standard on both a seasonal and station basis.

List of Figures

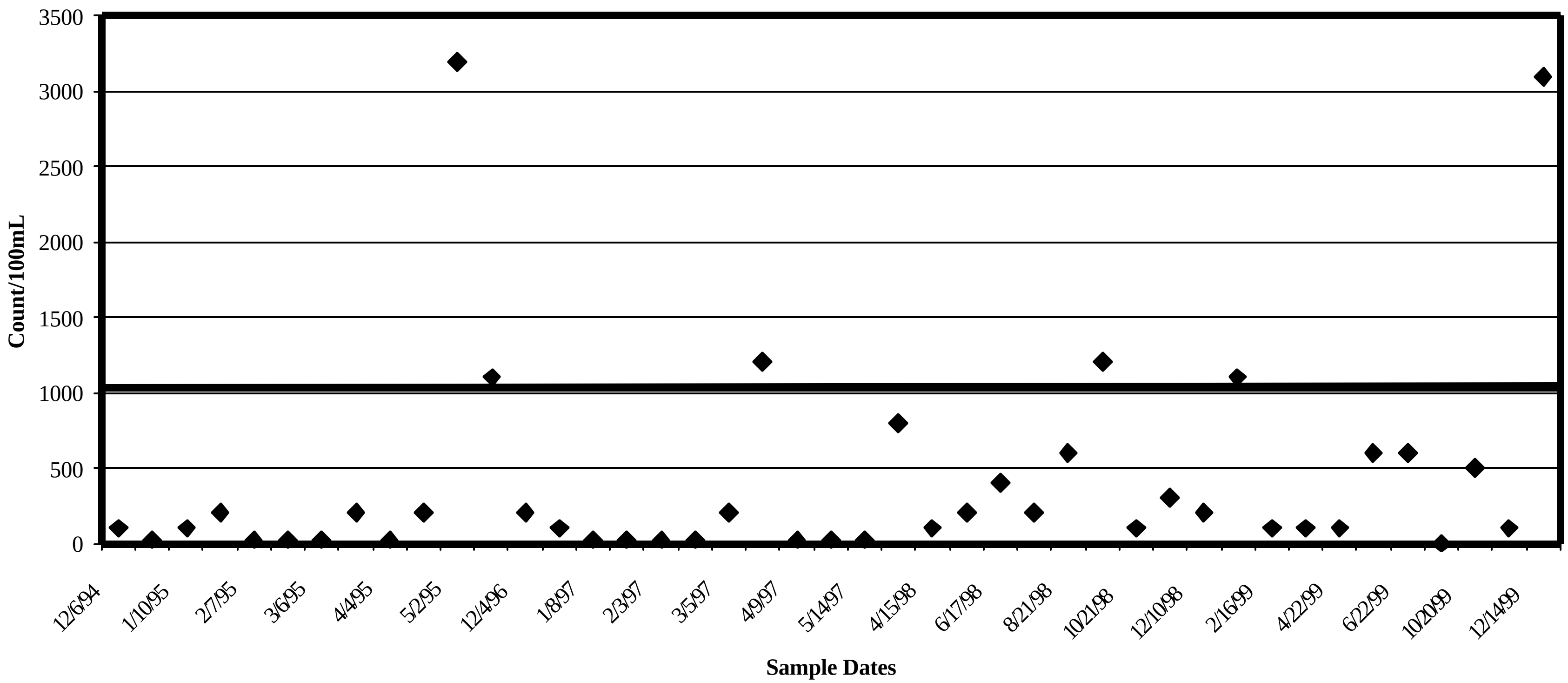

Figure A-1. Fecal Coliform Levels Measured at HCWC 1 (1994-1999)

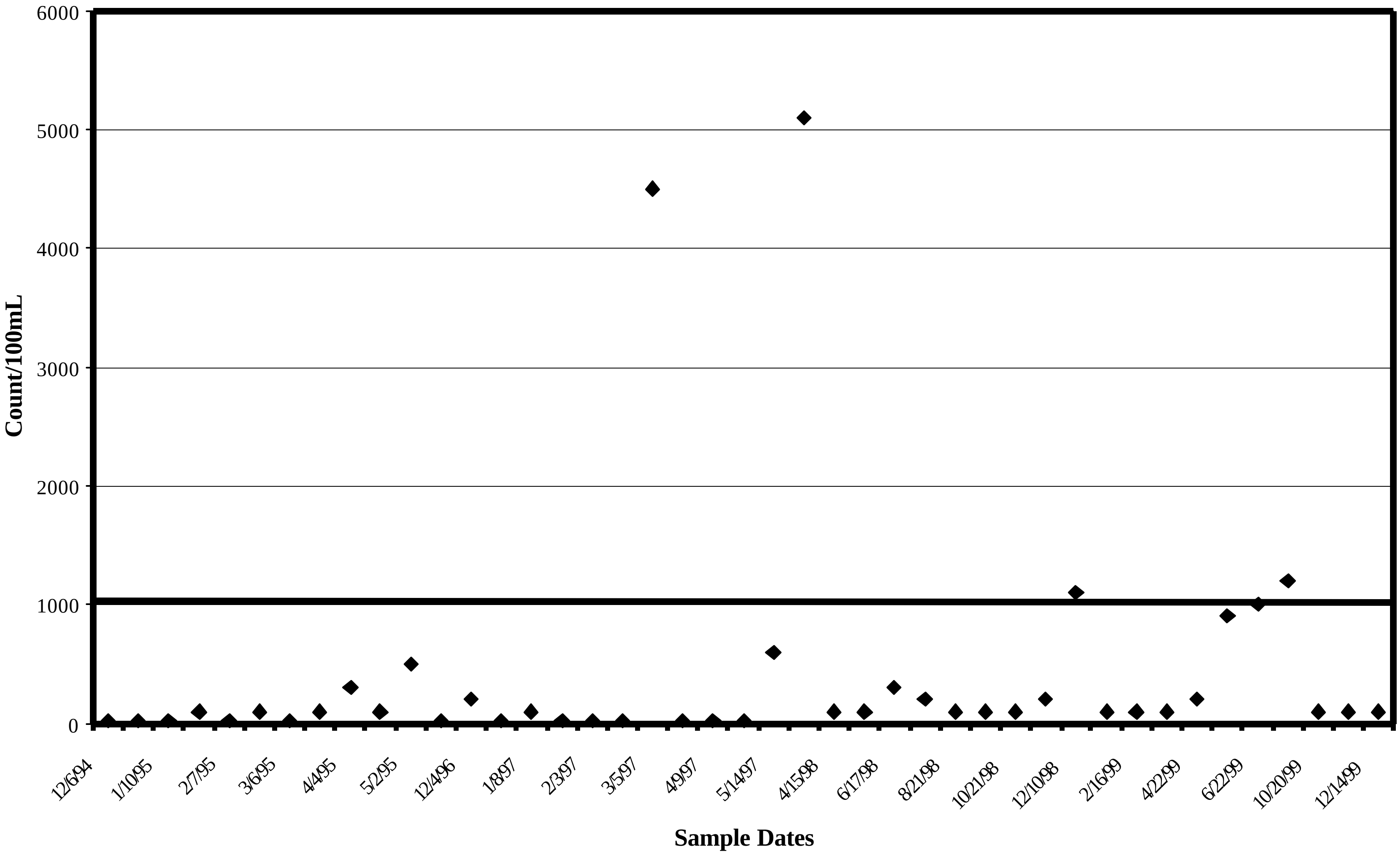

Figure A-2. Fecal Coliform Levels Measured at HCWC 3 (1994-1999)

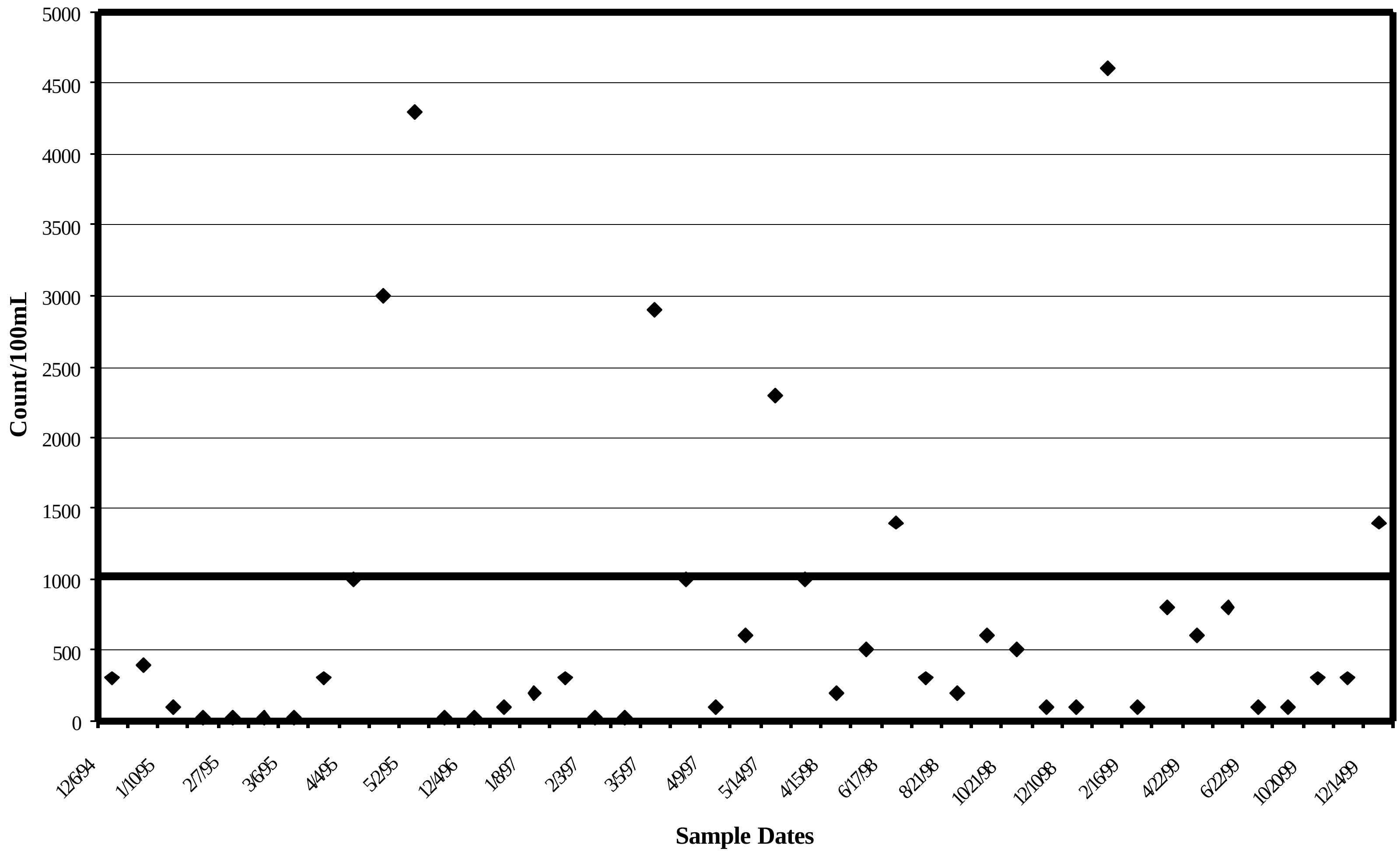

Figure A-3. Fecal Coliform Levels Measured at HCWC 3 (1994-1999)

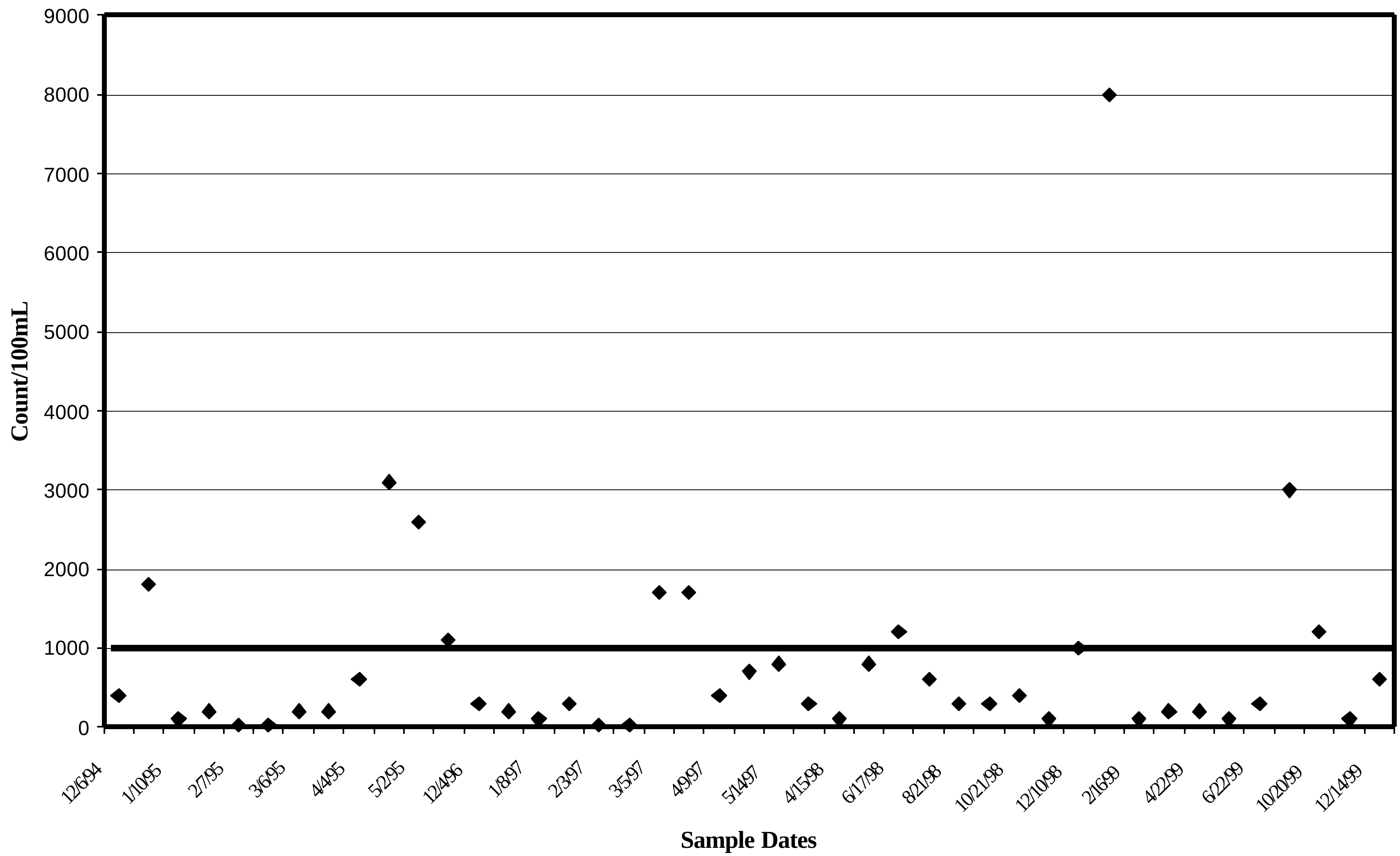

Figure A-4. Fecal Coliform Levels Measured at HCWC 4 (1994-1999)

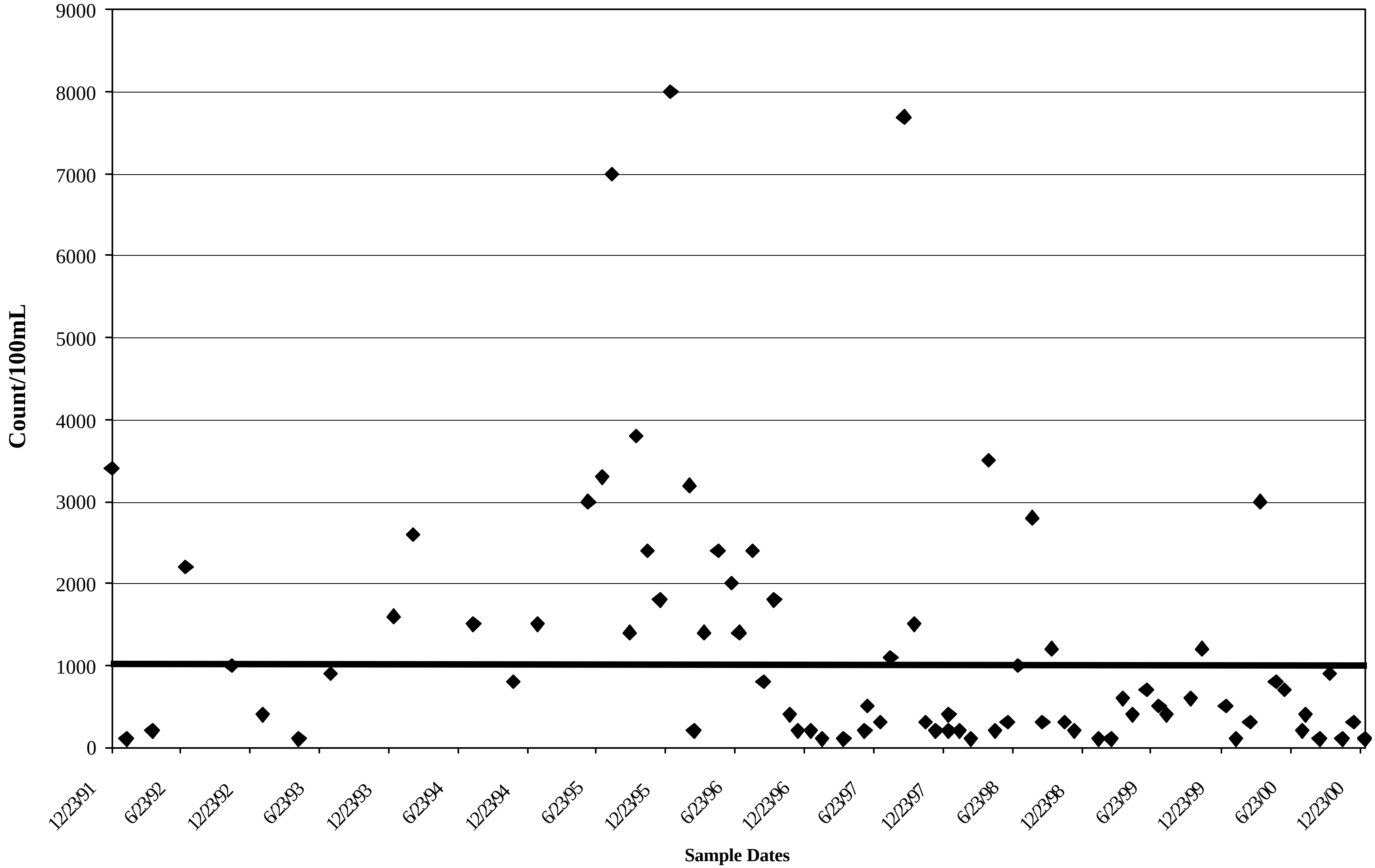

Figure A-5. Fecal Coliform Levels Measured at the VADEQ Station (1991-1998)

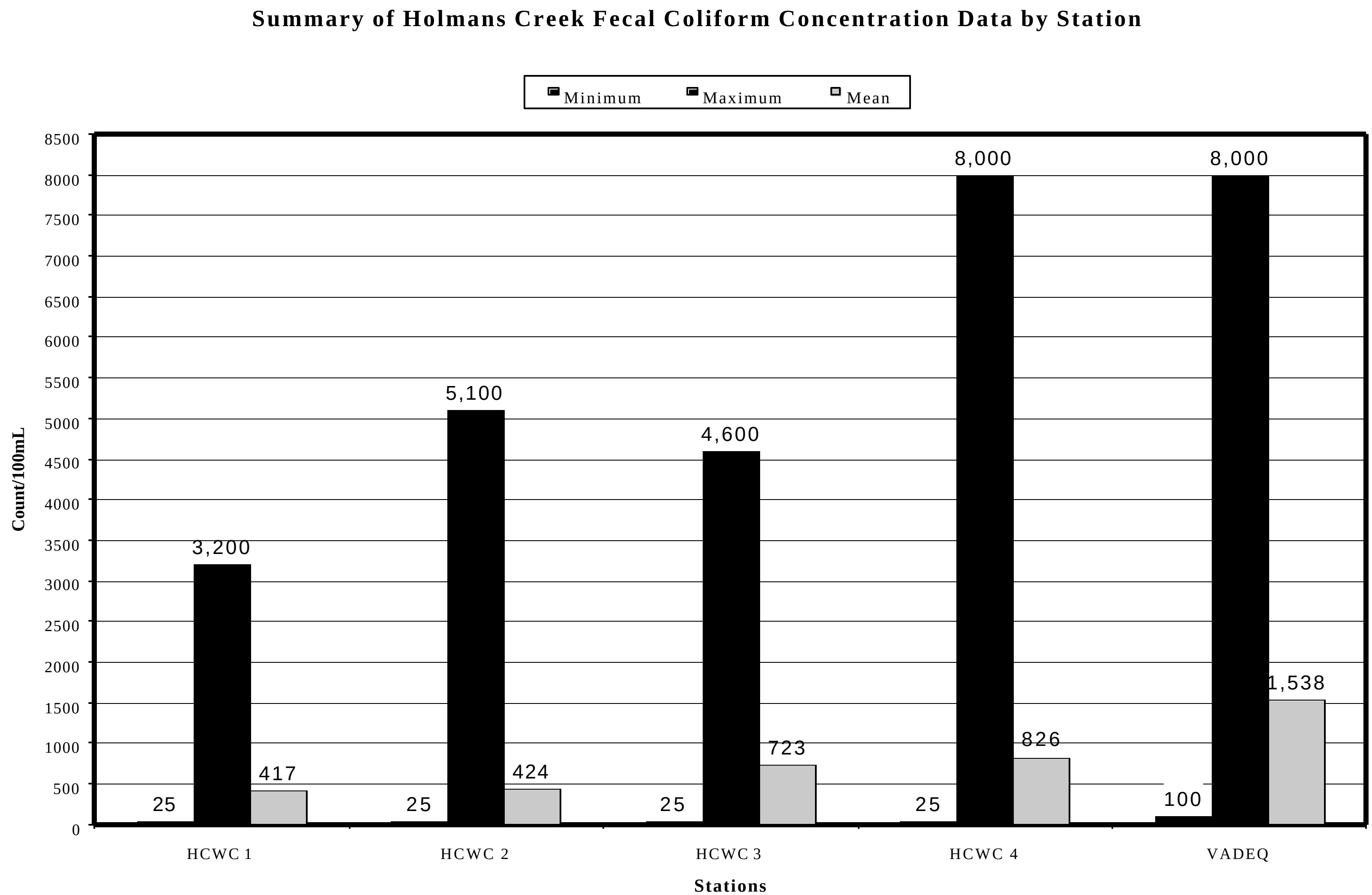

Figure A-6. Summary of Holmans Creek Fecal Coliform Concentration Data by Station

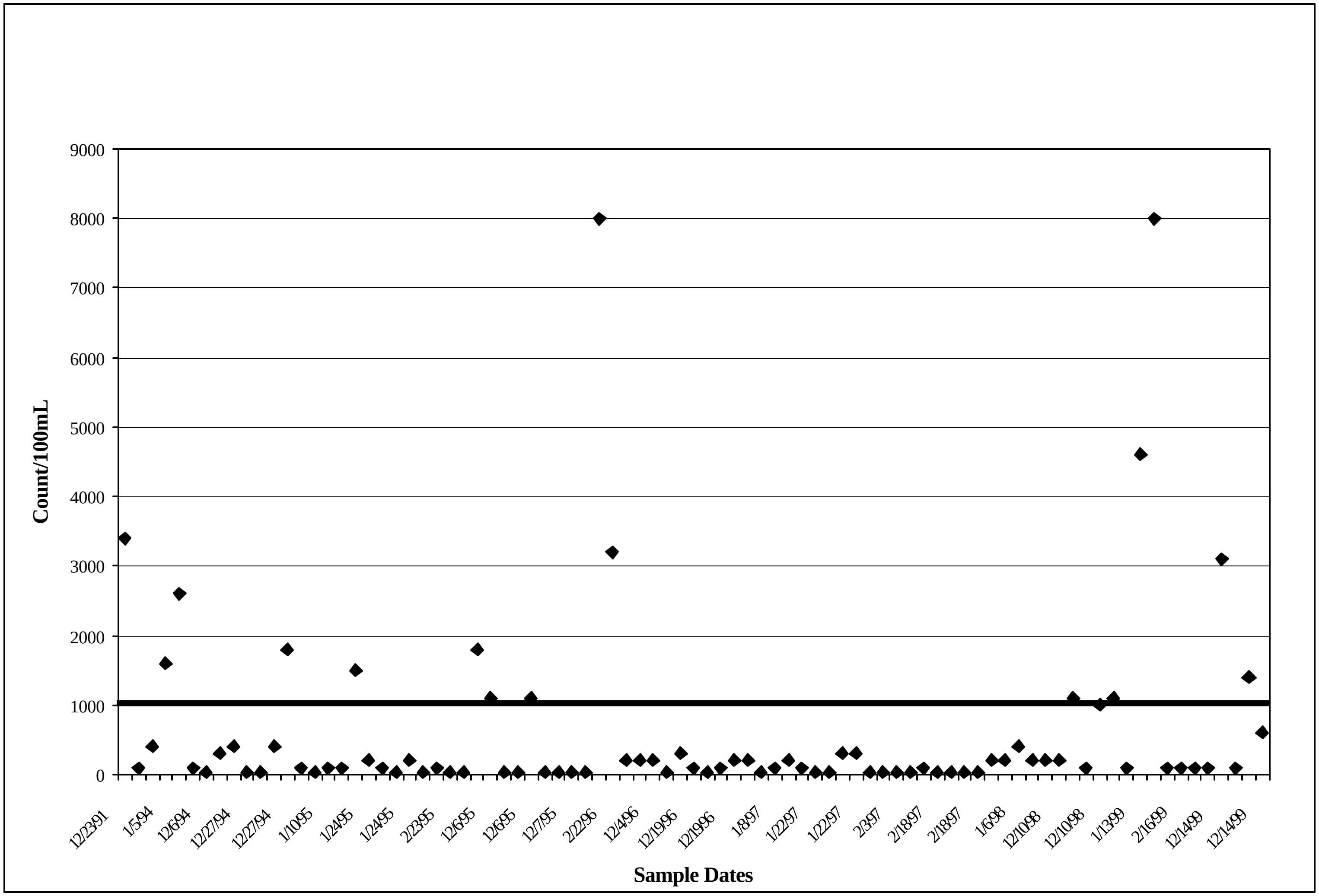

Figure A-7. Fecal Coliform Levels Measured from December-February for All Stations (1991-1999)

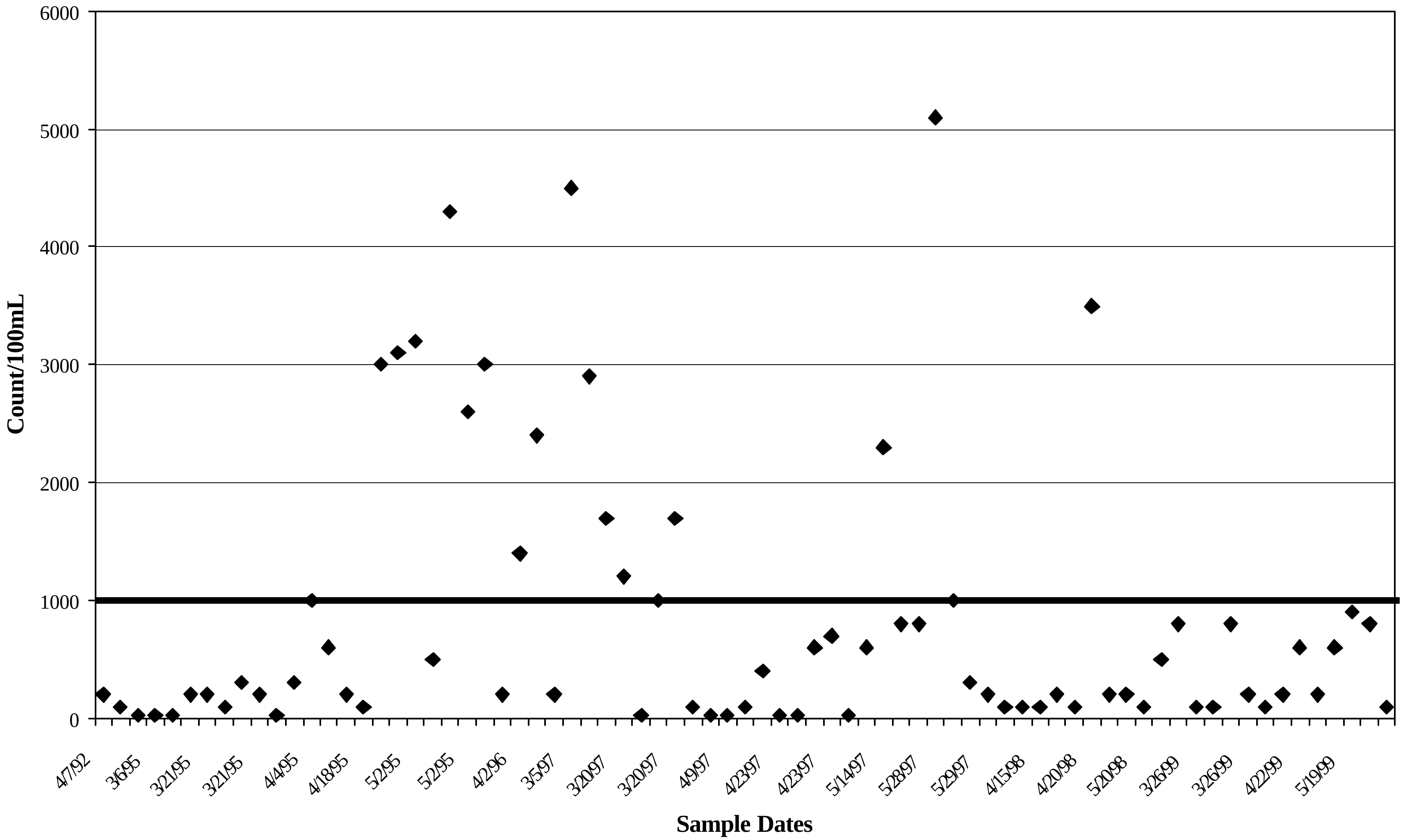

Figure A-8. Fecal Coliform Levels Measured from March - May for All Stations (1992-1999)

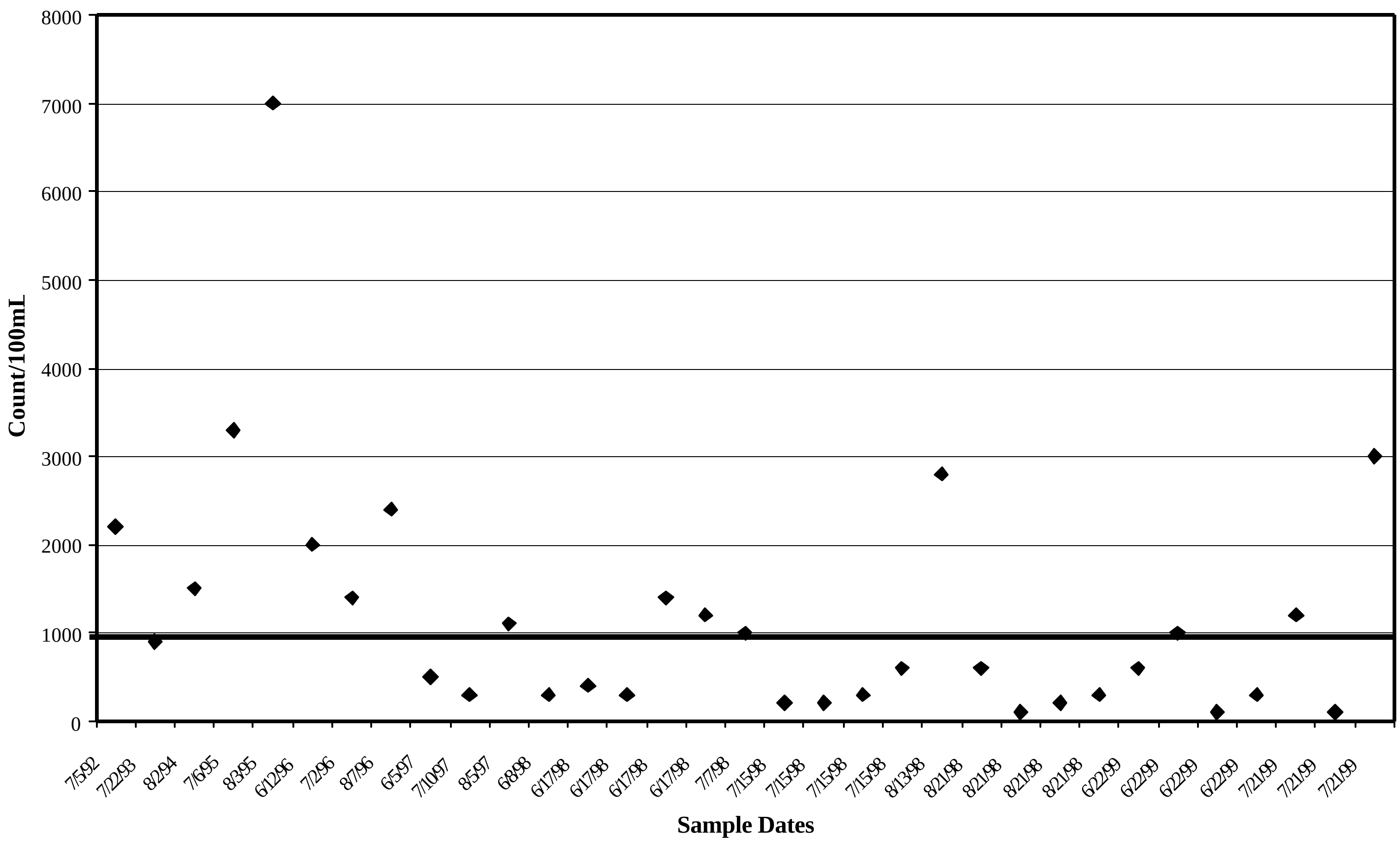

Figure A-9. Fecal Coliform Levels Measured from June - August for All Stations (1992-1999)

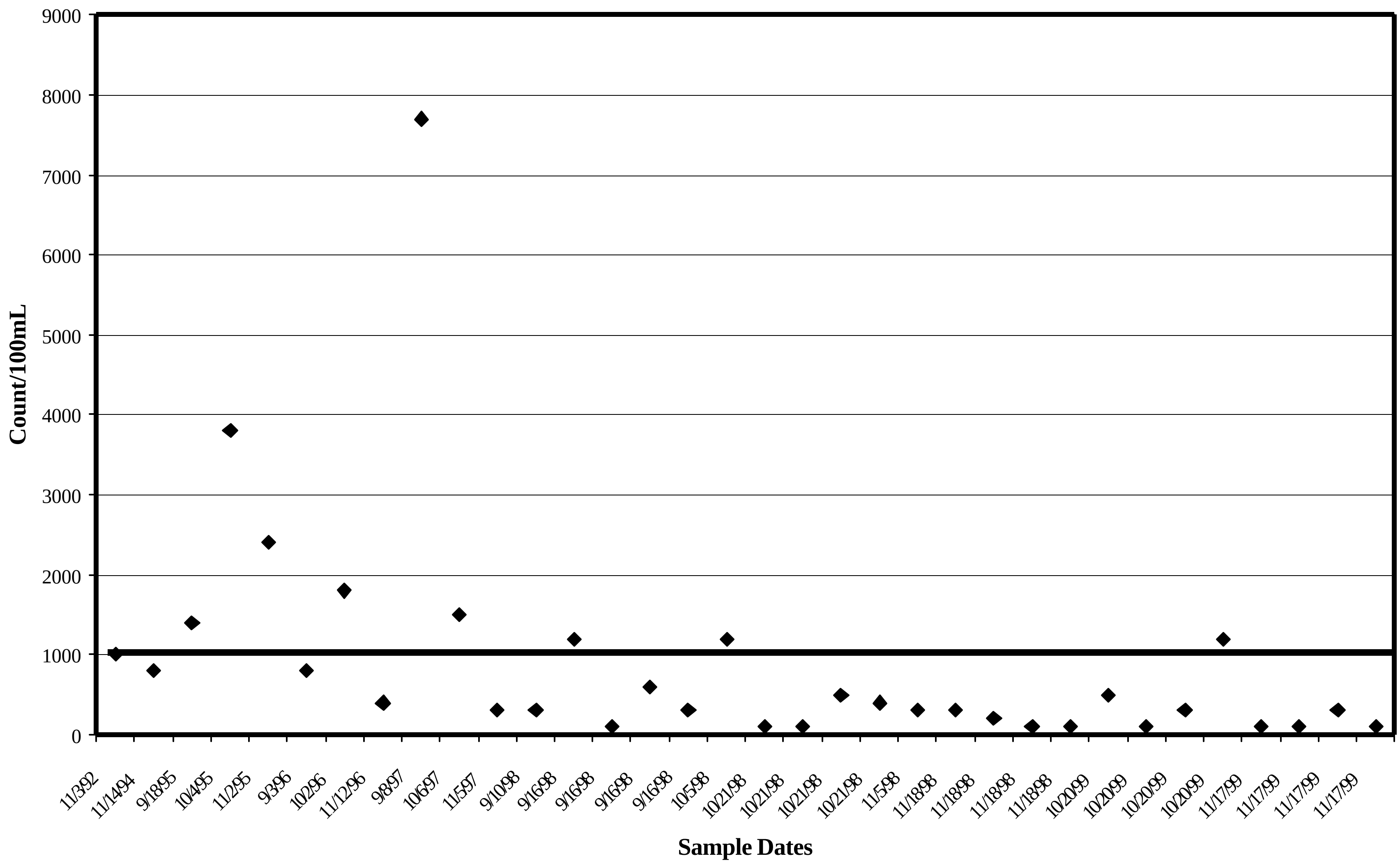

Figure A-10. Fecal Coliform Levels Measured from September - November for All Stations (1992-1999)

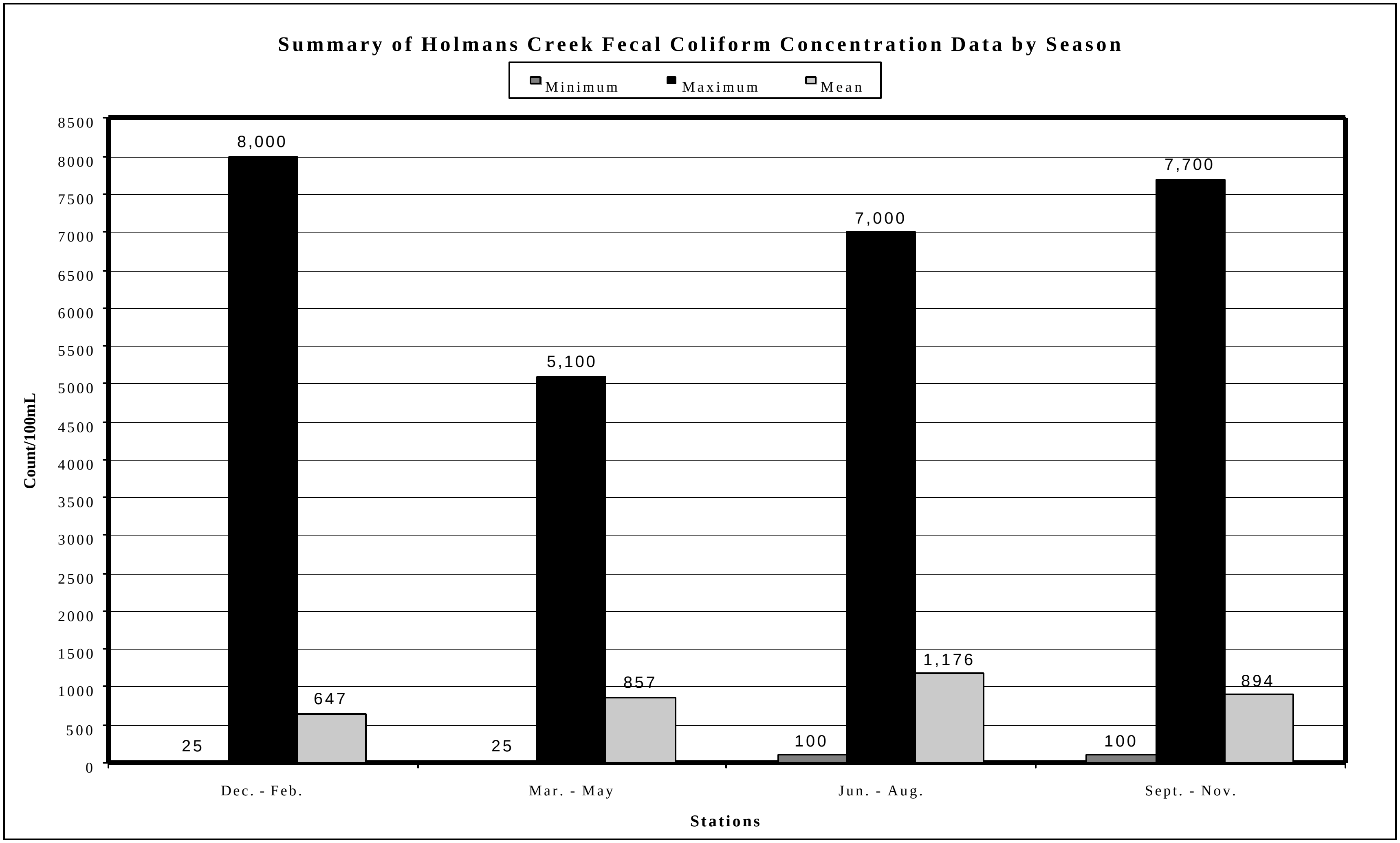

Figure A-11. Summary of Holmans Creek Fecal Coliform Concentration Data by Season

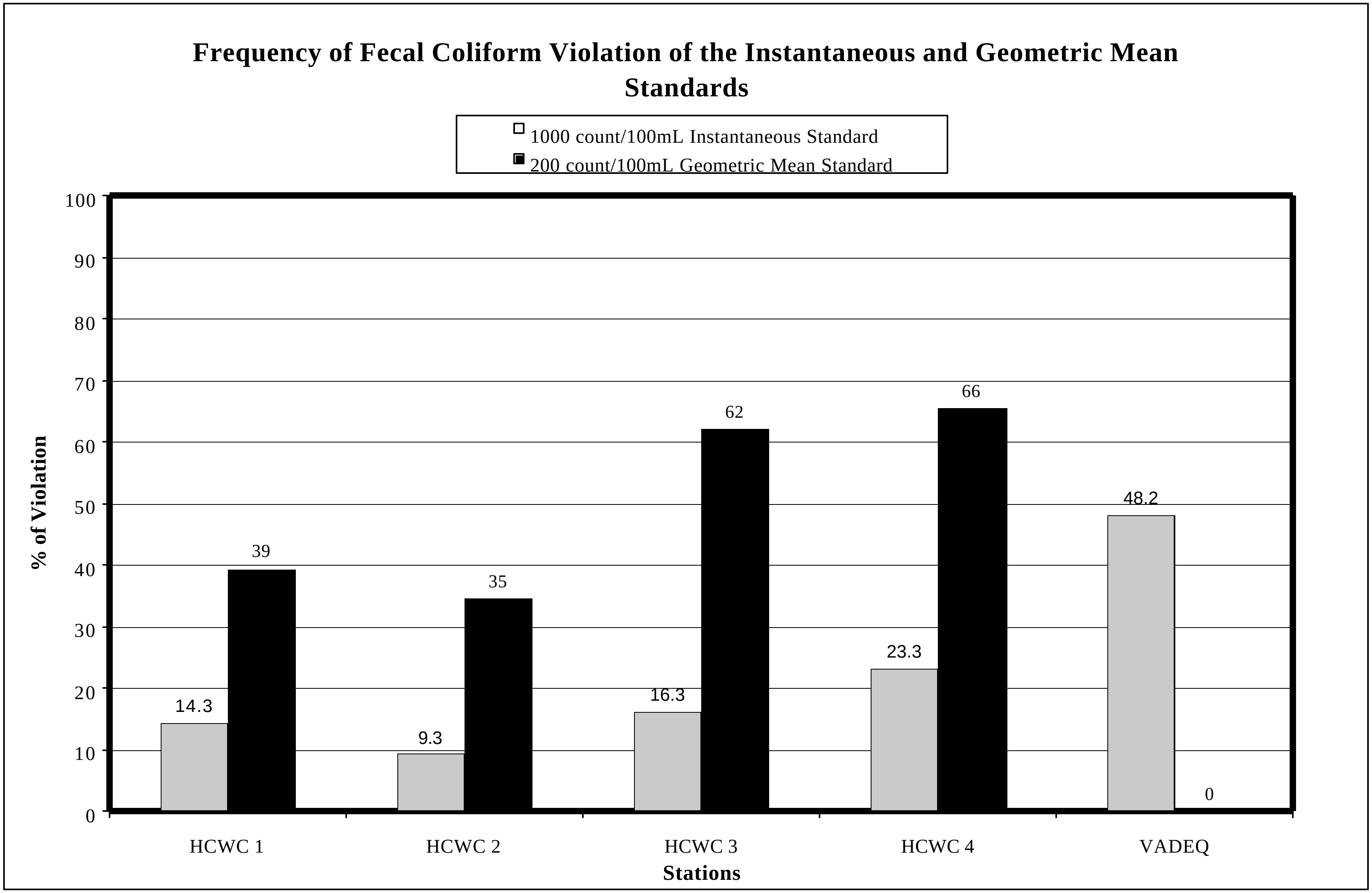

Figure A-12. Frequency of Fecal Coliform Violation of the Single Instantaneous and Geometric Mean Standards

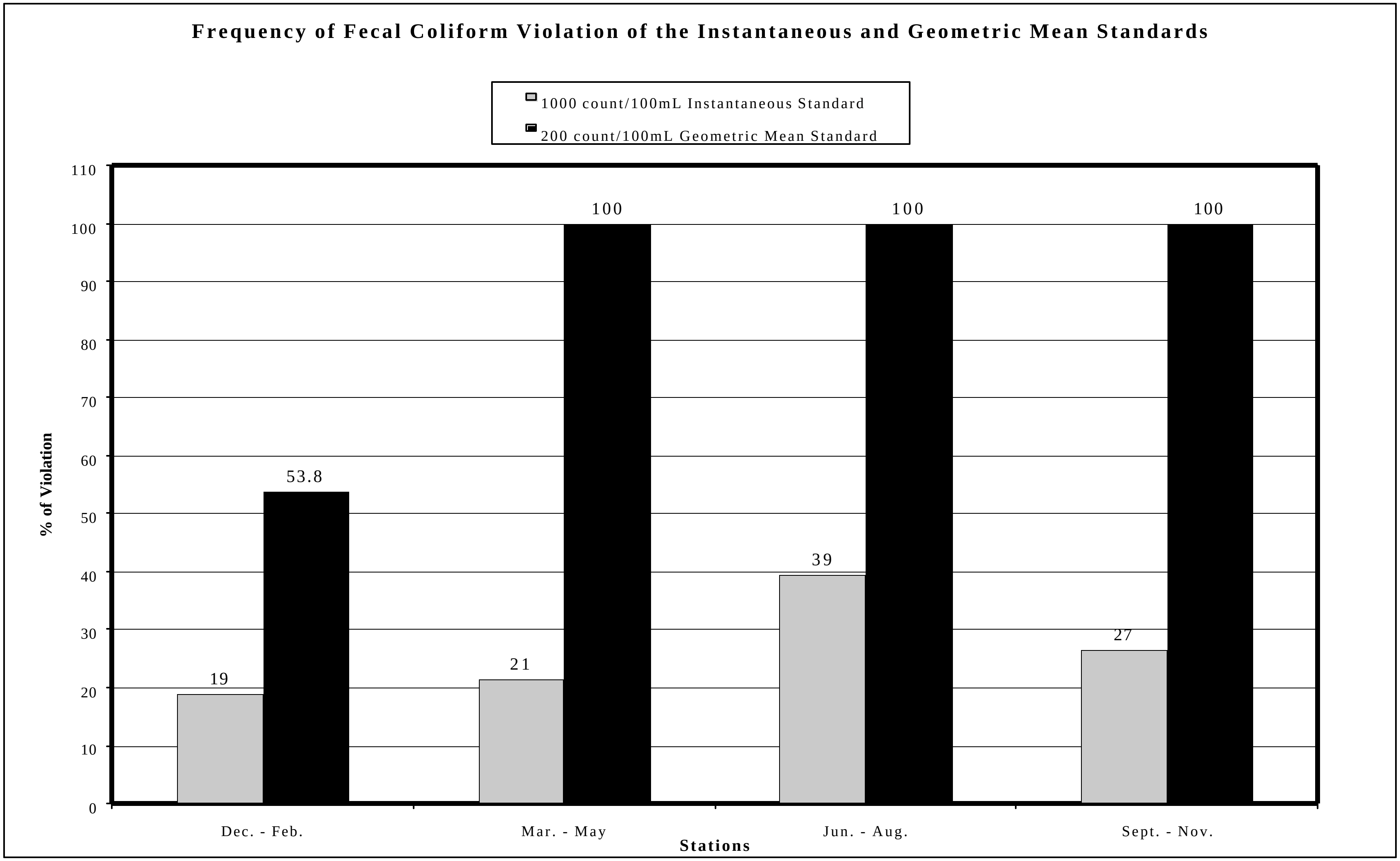

Figure A-13. Frequency of Fecal Coliform Violation of the Instantaneous and Geometric Mean Standards by Station

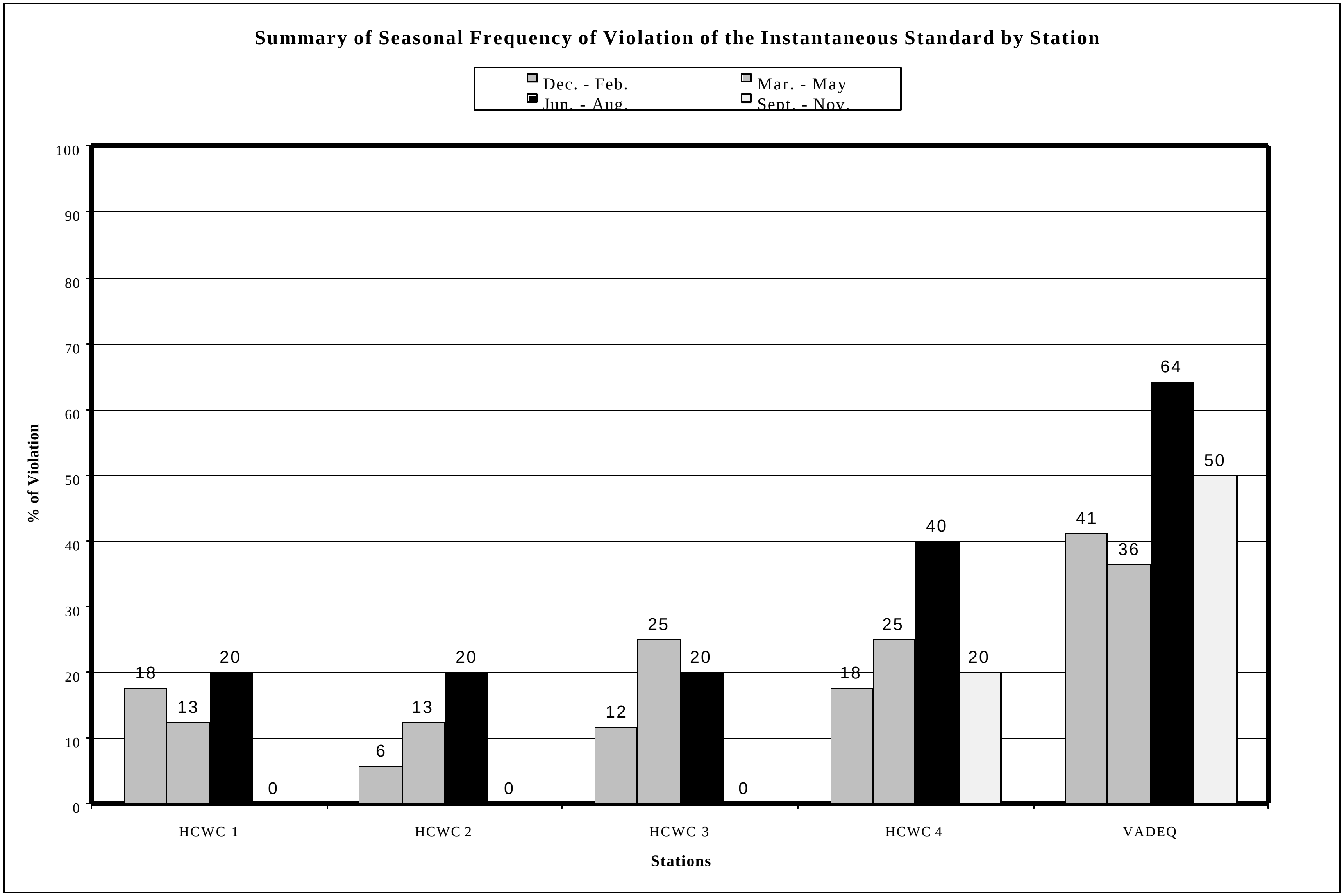

Figure A-14. Seasonal Frequency of Violation of the Instantaneous Standard by Station

APPENDIX B

(Fecal Coliform Deposition Pathways)

Figure B-1 presents the sources of fecal coliform and their method of deposition to the land use categories present in the Holmans Creek watershed. Direct sources are septic systems, wildlife, unconfined dairy and unconfined beef cattle. Indirect sources are wildlife, pets, confined poultry, confined dairy, unconfined dairy, and unconfined beef cattle. As indicated by the Figure, wildlife sources are distributed to each of the seven land uses, while pets apply only to two land uses, confined poultry apply to three land uses, confined dairy apply to only one land use, and unconfined dairy and unconfined beef cattle apply to only one land use.

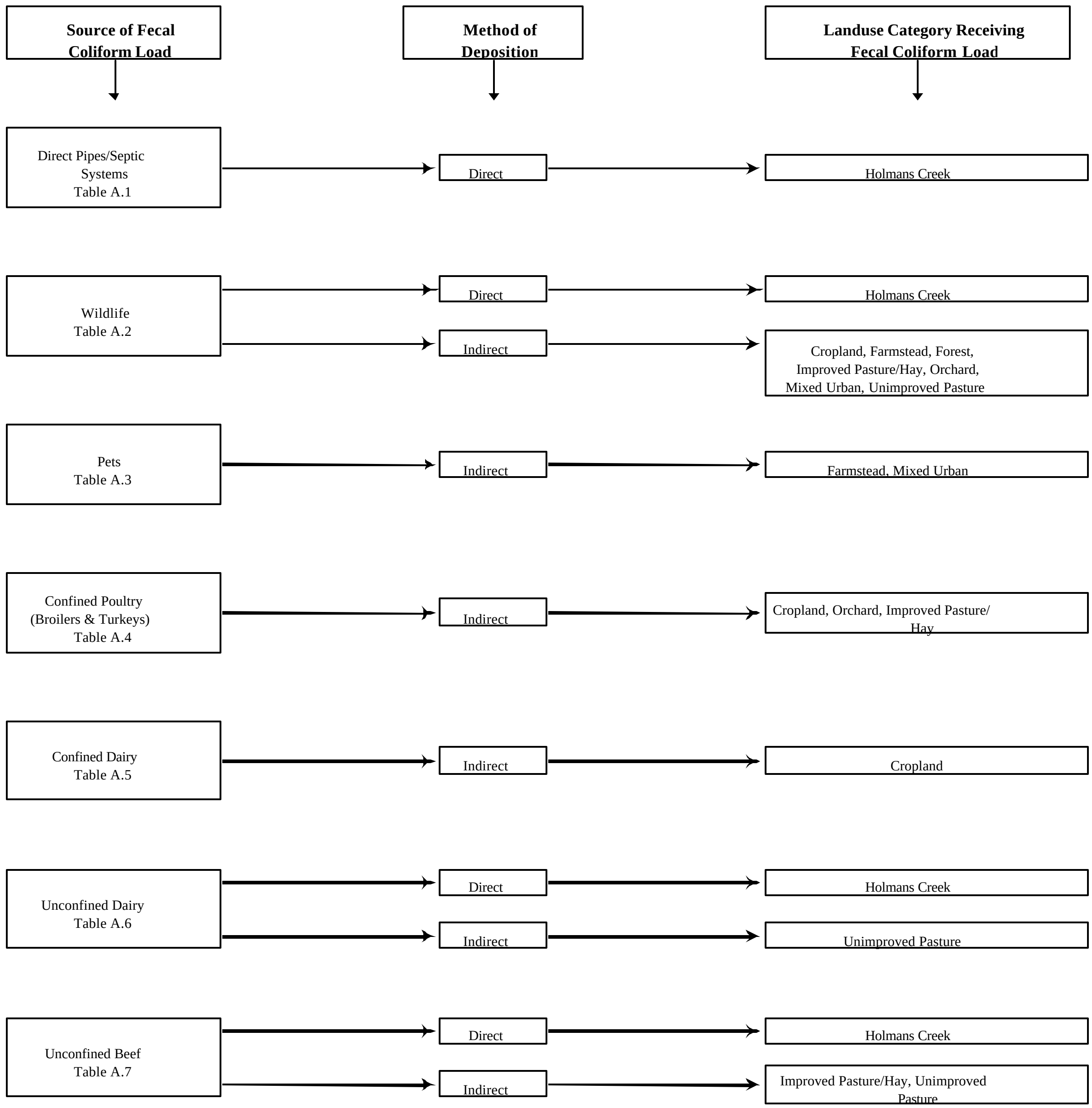

Figure B-1. Fecal Coliform Load Summary

APPENDIX C

(Fecal Coliform Load Conversions)

The model requires the fecal coliform loadings from indirect sources to be expressed as fecal coliform application rates in counts/acre/day for each land use in each sub-watershed for each month. Since the fecal coliform loads from indirect sources were derived by land use on a monthly or yearly basis, a basic conversion from counts/month or counts/year to counts/day/acre was performed. All yearly fecal coliform loads (septic, wildlife and pets) were converted to counts/month as follows: yearly fecal coliform loads (counts/year) divided by the number of days (365.25) and then multiplied by the number of days in each month. All monthly fecal coliform loads (confined poultry, confined dairy, unconfined dairy, and unconfined beef) values were taken directly from the calculation in Section 5.4 of the Model Input. Tables C-1 through C-7 present the fecal coliform loading per month for each source by land use in each sub-watershed.

Indirect source values (counts/month) in the above tables were divided by the number of days in the month and the total acreage of the land use to yield the counts/acre/day as required for the model. Tables C-8 through C-11 provide the fecal coliform values used in the model for each sub-watershed. The indirect source loadings are expressed as counts/acre/day for each land use in each sub-watershed. The direct source loadings are expressed as counts/month for each land use in each sub-watershed.

Table C-1. Monthly Fecal Coliform Loads from Septic Systems

Sub-watershed	Land Use	January (counts)	February (counts)	March (counts)	April (counts)	May (counts)	June (counts)	July (counts)	August (counts)	September (counts)	October (counts)	November (counts)	December (counts)
HC-1	Stream	6.40E+11	5.88E+11	6.40E+11	6.19E+11	6.40E+11	6.19E+11	6.40E+11	6.40E+11	6.19E+11	6.40E+11	6.19E+11	6.40E+11
HC-2	Stream	5.09E+11	4.68E+11	5.09E+11	4.92E+11	5.09E+11	4.92E+11	5.09E+11	5.09E+11	4.92E+11	5.09E+11	4.92E+11	5.09E+11
HC-3	Stream	1.13E+12	1.04E+12	1.13E+12	1.10E+12	1.13E+12	1.10E+12	1.13E+12	1.13E+12	1.10E+12	1.13E+12	1.10E+12	1.13E+12
HC-4	Stream	1.46E+12	1.34E+12	1.46E+12	1.41E+12	1.46E+12	1.41E+12	1.46E+12	1.46E+12	1.41E+12	1.46E+12	1.41E+12	1.46E+12

All values taken from Section 5.4 of the Model Input

Table C-2. Monthly Fecal Coliform Loads from Wildlife

Sub-watershed	Land Use	January (counts)	February (counts)	March (counts)	April (counts)	May (counts)	June (counts)	July (counts)	August (counts)	September (counts)	October (counts)	November (counts)	December (counts)
HC-1	Cropland	7.66E+11	6.92E+11	7.66E+11	7.66E+11	7.66E+11	7.66E+11	7.66E+11	7.66E+11	7.66E+11	7.66E+11	7.66E+11	7.66E+11
	Forest	7.68E+12	7.06E+12	7.68E+12	7.43E+12	7.68E+12	7.43E+12	7.68E+12	7.68E+12	7.43E+12	7.68E+12	7.43E+12	7.68E+12
	Orchard	4.60E+11	4.22E+11	4.60E+11	4.45E+11	4.60E+11	4.45E+11	4.60E+11	4.60E+11	4.45E+11	4.60E+11	4.45E+11	4.60E+11
	Improved Pasture/Hay	6.49E+12	5.96E+12	6.49E+12	6.28E+12	6.49E+12	6.28E+12	6.49E+12	6.49E+12	6.28E+12	6.49E+12	6.28E+12	6.49E+12
	Unimproved Pasture	4.55E+11	4.18E+11	4.55E+11	4.40E+11	4.55E+11	4.40E+11	4.55E+11	4.55E+11	4.40E+11	4.55E+11	4.40E+11	4.55E+11
	Mixed Urban	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Farmstead	5.59E+11	5.14E+11	5.59E+11	5.41E+11	5.59E+11	5.41E+11	5.59E+11	5.59E+11	5.41E+11	5.59E+11	5.41E+11	5.59E+11
	Stream	7.96E+12	7.32E+12	7.96E+12	7.71E+12	7.96E+12	7.71E+12	7.96E+12	7.96E+12	7.71E+12	7.96E+12	7.71E+12	7.96E+12
HC-2	Cropland	3.33E+11	3.06E+11	3.33E+11	3.22E+11	3.33E+11	3.22E+11	3.33E+11	3.33E+11	3.22E+11	3.33E+11	3.22E+11	3.33E+11
	Forest	2.85E+12	2.62E+12	2.85E+12	2.76E+12	2.85E+12	2.76E+12	2.85E+12	2.85E+12	2.76E+12	2.85E+12	2.76E+12	2.85E+12
	Orchard	3.29E+12	3.03E+12	3.29E+12	3.19E+12	3.29E+12	3.19E+12	3.29E+12	3.29E+12	3.19E+12	3.29E+12	3.19E+12	3.29E+12
	Improved Pasture/Hay	1.78E+12	1.64E+12	1.78E+12	1.72E+12	1.78E+12	1.72E+12	1.78E+12	1.78E+12	1.72E+12	1.78E+12	1.72E+12	1.78E+12
	Unimproved Pasture	1.42E+12	1.30E+12	1.42E+12	1.37E+12	1.42E+12	1.37E+12	1.42E+12	1.42E+12	1.37E+12	1.42E+12	1.37E+12	1.42E+12
	Mixed Urban	4.58E+10	4.21E+10	4.58E+10	4.43E+10	4.58E+10	4.43E+10	4.58E+10	4.58E+10	4.43E+10	4.58E+10	4.43E+10	4.58E+10
	Farmstead	1.19E+11	1.09E+11	1.19E+11	1.15E+11	1.19E+11	1.15E+11	1.19E+11	1.19E+11	1.15E+11	1.19E+11	1.15E+11	1.19E+11
	Stream	6.65E+12	6.12E+12	6.65E+12	6.44E+12	6.65E+12	6.44E+12	6.65E+12	6.65E+12	6.44E+12	6.65E+12	6.44E+12	6.65E+12
HC-3	Cropland	1.89E+12	1.74E+12	1.89E+12	1.83E+12	1.89E+12	1.83E+12	1.89E+12	1.89E+12	1.83E+12	1.89E+12	1.83E+12	1.89E+12
	Forest	7.94E+12	7.30E+12	7.94E+12	7.68E+12	7.94E+12	7.68E+12	7.94E+12	7.94E+12	7.68E+12	7.94E+12	7.68E+12	7.94E+12
	Orchard	1.16E+12	1.07E+12	1.16E+12	1.12E+12	1.16E+12	1.12E+12	1.16E+12	1.16E+12	1.12E+12	1.16E+12	1.12E+12	1.16E+12
	Improved Pasture/Hay	6.71E+12	6.16E+12	6.71E+12	6.49E+12	6.71E+12	6.49E+12	6.71E+12	6.71E+12	6.49E+12	6.71E+12	6.49E+12	6.71E+12
	Unimproved Pasture	1.47E+12	1.35E+12	1.47E+12	1.43E+12	1.47E+12	1.43E+12	1.47E+12	1.47E+12	1.43E+12	1.47E+12	1.43E+12	1.47E+12
	Mixed Urban	1.44E+11	1.33E+11	1.44E+11	1.40E+11	1.44E+11	1.40E+11	1.44E+11	1.44E+11	1.40E+11	1.44E+11	1.40E+11	1.44E+11
	Farmstead	3.80E+11	3.49E+11	3.80E+11	3.67E+11	3.80E+11	3.67E+11	3.80E+11	3.80E+11	3.67E+11	3.80E+11	3.67E+11	3.80E+11
	Stream	9.86E+12	9.07E+12	9.86E+12	9.54E+12	9.86E+12	9.54E+12	9.86E+12	9.86E+12	9.54E+12	9.86E+12	9.54E+12	9.86E+12

Table C-2. Monthly Fecal Coliform Loads from Wildlife (Continued)

Sub-watershed	Land Use	January (counts)	February (counts)	March (counts)	April (counts)	May (counts)	June (counts)	July (counts)	August (counts)	September (counts)	October (counts)	November (counts)	December (counts)
HC-4	Cropland	3.69E+12	3.39E+12	3.69E+12	3.57E+12	3.69E+12	3.57E+12	3.69E+12	3.69E+12	3.57E+12	3.69E+12	3.57E+12	3.69E+12
	Forest	1.47E+13	1.36E+13	1.47E+13	1.43E+13	1.47E+13	1.43E+13	1.47E+13	1.47E+13	1.43E+13	1.47E+13	1.43E+13	1.47E+13
	Orchard	1.44E+12	1.32E+12	1.44E+12	1.39E+12	1.44E+12	1.39E+12	1.44E+12	1.44E+12	1.39E+12	1.44E+12	1.39E+12	1.44E+12
	Improved Pasture/Hay	1.31E+13	1.20E+13	1.31E+13	1.26E+13	1.31E+13	1.26E+13	1.31E+13	1.31E+13	1.26E+13	1.31E+13	1.26E+13	1.31E+13
	Unimproved Pasture	5.65E+11	5.20E+11	5.65E+11	5.47E+11	5.65E+11	5.47E+11	5.65E+11	5.65E+11	5.47E+11	5.65E+11	5.47E+11	5.65E+11
	Mixed Urban	7.81E+11	7.18E+11	7.81E+11	7.55E+11	7.81E+11	7.55E+11	7.81E+11	7.81E+11	7.55E+11	7.81E+11	7.55E+11	7.81E+11
	Farmstead	4.63E+11	4.25E+11	4.63E+11	4.48E+11	4.63E+11	4.48E+11	4.63E+11	4.63E+11	4.48E+11	4.63E+11	4.48E+11	4.63E+11
	Stream	1.63E+13	1.50E+13	1.63E+13	1.58E+13	1.63E+13	1.58E+13	1.63E+13	1.63E+13	1.58E+13	1.63E+13	1.58E+13	1.63E+13

All values taken from Section 5.4 of the Model Input

Table C-3. Monthly Fecal Coliform Loads from Pets

Sub-watershed	Land Use	January (counts)	February (counts)	March (counts)	April (counts)	May (counts)	June (counts)	July (counts)	August (counts)	September (counts)	October (counts)	November (counts)	December (counts)
HC-1	Farmstead	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Mixed Urban	3.00E+11	2.76E+11	3.00E+11	2.91E+11	3.00E+11	2.91E+11	3.00E+11	3.00E+11	2.91E+11	3.00E+11	2.91E+11	3.00E+11
HC-2	Farmstead	1.21E+11	1.11E+11	1.21E+11	1.17E+11	1.21E+11	1.17E+11	1.21E+11	1.21E+11	1.17E+11	1.21E+11	1.17E+11	1.21E+11
	Mixed Urban	1.21E+11	1.11E+11	1.21E+11	1.17E+11	1.21E+11	1.17E+11	1.21E+11	1.21E+11	1.17E+11	1.21E+11	1.17E+11	1.21E+11
HC-3	Farmstead	2.66E+11	2.45E+11	2.66E+11	2.58E+11	2.66E+11	2.58E+11	2.66E+11	2.66E+11	2.58E+11	2.66E+11	2.58E+11	2.66E+11
	Mixed Urban	2.66E+11	2.45E+11	2.66E+11	2.58E+11	2.66E+11	2.58E+11	2.66E+11	2.66E+11	2.58E+11	2.66E+11	2.58E+11	2.66E+11
HC-4	Farmstead	3.44E+11	3.17E+11	3.44E+11	3.33E+11	3.44E+11	3.33E+11	3.44E+11	3.44E+11	3.33E+11	3.44E+11	3.33E+11	3.44E+11
	Mixed Urban	3.44E+11	3.17E+11	3.44E+11	3.33E+11	3.44E+11	3.33E+11	3.44E+11	3.44E+11	3.33E+11	3.44E+11	3.33E+11	3.44E+11

All values taken from Section 5.4 of the Model Input

Table C-4. Monthly Fecal Coliform Loads from Poultry

Sub-watershed	Land Use	January (counts)	February (counts)	March (counts)	April (counts)	May (counts)	June (counts)	July (counts)	August (counts)	September (counts)	October (counts)	November (counts)	December (counts)
HC-1	Cropland	0.00E+00	0.00E+00	1.01E+14	1.92E+14	2.96E+14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.94E+14	2.49E+14	0.00E+00
	Improved Pasture/Hay	4.46E+13	1.01E+14	2.08E+14	3.95E+14	6.10E+14	2.16E+14	1.31E+14	2.31E+14	5.94E+14	0.00E+00	0.00E+00	1.77E+14
	Orchard	0.00E+00	0.00E+00	9.40E+12	1.79E+13	2.76E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HC-2	Cropland	0.00E+00	0.00E+00	1.41E+14	2.68E+14	4.13E+14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.18E+15	3.70E+14	0.00E+00
	Improved Pasture/Hay	6.63E+13	1.50E+14	7.878+13	1.50E+14	2.31E+14	3.21E+14	1.95E+14	3.43E+14	8.82E+14	0.00E+00	0.00E+00	2.62E+14
	Orchard	0.00E+00	0.00E+00	2.53E+14	4.81E+14	7.42E+14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HC-3	Cropland	0.00E+00	0.00E+00	1.85E+10	3.64E+10	5.43E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.95E+10	2.90E+10	0.00E+00
	Improved Pasture/Hay	4.04E+13	9.16E+13	1.22E+14	2.32E+14	3.58E+14	1.96E+14	1.19E+14	2.09E+14	5.37E+14	0.00E+00	0.00E+00	1.60E+14
	Orchard	0.00E+00	0.00E+00	1.74E+13	3.30E+13	5.09E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HC-4	Cropland	0.00E+00	0.00E+00	1.13E+15	2.15E+15	3.32E+15	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.88E+15	1.22E+15	0.00E+00
	Improved Pasture/Hay	2.18E+14	4.95E+14	3.75E+14	7.14E+14	1.10E+15	1.06E+15	6.42E+14	1.13E+15	2.90E+15	0.00E+00	0.00E+00	8.64E+14
	Orchard	0.00E+00	0.00E+00	4.86E+13	9.25E+13	1.43E+14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

All values taken from Section 5.4 of the Model Input

Table C-5. Monthly Fecal Coliform Loads from Confined Dairy Cows

Sub-watershed	Land Use	January (counts)	February (counts)	March (counts)	April (counts)	May (counts)	June (counts)	July (counts)	August (counts)	September (counts)	October (counts)	November (counts)	December (counts)
HC-3	Cropland	0.00E+00	3.09E+08	1.80E+09	3.23E+09	3.29E+09	0.00E+00	0.00E+00	3.95E+08	1.63E+09	1.67E+09	1.72E+09	0.00E+00

All values taken from Section 5.4 of the Model Input

Table C-6. Monthly Fecal Coliform Loads from Unconfined Dairy Cows

Sub-watershed	Land Use	January (counts)	February (counts)	March (counts)	April (counts)	May (counts)	June (counts)	July (counts)	August (counts)	September (counts)	October (counts)	November (counts)	December (counts)
HC-3	Unimproved Pasture	2.76E+12	2.51E+12	2.76E+12	4.26E+12	5.50E+12	5.32E+12	5.50E+12	5.50E+12	5.33E+12	5.51E+12	4.27E+12	2.76E+12
	Stream	3.45E+09	3.15E+09	6.91E+09	1.60E+10	2.07E+10	2.67E+10	2.76E+10	2.76E+10	2.00E+10	1.38E+10	1.07E+10	3.45E+09

* All values taken from Section 5.4 of the Model Input

Table C-7. Monthly Fecal Coliform Loads from Unconfined Beef Cattle

Sub-watershed	Land Use	January (counts)	February (counts)	March (counts)	April (counts)	May (counts)	June (counts)	July (counts)	August (counts)	September (counts)	October (counts)	November (counts)	December (counts)
HC-1	Improved Pasture/Hay	2.30E+13	2.30E+13	2.29E+13	2.29E+13	2.29E+13	2.29E+13	2.29E+13	2.29E+13	2.29E+13	2.29E+13	2.29E+13	2.30E+13
	Unimproved Pasture	2.30E+13	2.30E+13	2.29E+13	2.29E+13	2.29E+13	2.29E+13	2.29E+13	2.29E+13	2.29E+13	2.29E+13	2.29E+13	2.30E+13
	Stream	1.15E+11	1.15E+11	1.73E+11	2.30E+11	2.30E+11	2.88E+11	2.88E+11	2.88E+11	2.30E+11	1.73E+11	1.73E+11	1.15E+11
HC-2	Improved Pasture/Hay	2.84E+13	2.84E+13	2.83E+13	2.83E+13	2.83E+13	2.83E+13	2.83E+13	2.83E+13	2.83E+13	2.83E+13	2.83E+13	2.84E+13
	Unimproved Pasture	2.84E+13	2.84E+13	2.83E+13	2.83E+13	2.83E+13	2.83E+13	2.83E+13	2.83E+13	2.83E+13	2.83E+13	2.83E+13	2.84E+13
	Stream	1.42+11	1.42+11	2.13E+11	2.84E+11	2.84E+11	3.55E+11	3.55E+11	3.55E+11	2.84E+11	2.13E+11	2.13E+11	1.42+11
HC-3	Improved Pasture/Hay	7.00E+13	7.00E+13	6.99E+13	6.98E+13	6.98E+13	6.97E+13	6.97E+13	6.97E+13	6.98E+13	6.99E+13	6.99E+13	7.00E+13
	Unimproved Pasture	7.00E+13	7.00E+13	6.99E+13	6.98E+13	6.98E+13	6.97E+13	6.97E+13	6.97E+13	6.98E+13	6.99E+13	6.99E+13	7.00E+13
	Stream	3.51E+11	3.51E+11	5.26E+11	7.02E+11	7.02E+11	8.77E+11	8.77E+11	8.77E+11	7.02E+11	5.26E+11	5.26E+11	3.51E+11
HC-4	Improved Pasture/Hay	3.52E+13	3.52E+13	3.52E+13	3.52E+13	3.52E+13	3.51E+13	3.51E+13	3.51E+13	3.52E+13	3.52E+13	3.52E+13	3.52E+13
	Unimproved Pasture	3.51E+13	3.51E+13	3.49E+13	3.48E+13	3.48E+13	3.47E+13	3.47E+13	3.47E+13	3.48E+13	3.49E+13	3.49E+13	3.51E+13
	Stream	1.77E+11	1.77E+11	2.65E+11	3.53E+11	3.53E+11	4.42E+11	4.42E+11	4.42E+11	3.53E+11	2.65E+11	2.65E+11	1.77E+11

All values taken from Section 5.4 of the Model Input

Table C-8. Monthly Fecal Coliform Loading Counts for HC-1 by Land Use

Land Use	January	February	March	April	May	June	July	August	September	October	November	December
Counts/Acre/Day												
Cropland	1.81E+08	1.81E+08	3.21E+10	6.29E+10	9.39E+10	1.81E+08	1.81E+08	1.81E+08	1.81E+08	2.51E+11	8.16E+10	1.81E+08
Farmstead	2.28E+08	2.28E+08	2.28E+08	2.28E+08	2.28E+08	2.28E+08	2.28E+08	2.28E+08	2.28E+08	2.28E+08	2.28E+08	2.28E+08
Forest	3.29E+08	3.29E+08	3.29E+08	3.29E+08	3.29E+08	3.29E+08	3.29E+08	3.29E+08	3.29E+08	3.29E+08	3.29E+08	3.29E+08
Mixed Urban	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Orchard	3.29E+08	3.29E+08	1.16E+10	2.24E+10	3.33E+10	3.29E+08	3.29E+08	3.29E+08	3.29E+08	3.29E+08	3.29E+08	3.29E+08
Improved Pasture/Hay*	1.46E+09	1.58E+09	1.31E+10	2.43E+10	3.55E+10	1.40E+10	8.79E+09	1.44E+10	3.58E+10	1.46E+09	1.50E+09	7.11E+09
Unimproved Pasture	9.32E+09	1.01E+10	9.31E+09	9.60E+09	9.30E+09	9.59E+09	9.28E+09	9.28E+09	9.60E+09	9.31E+09	9.61E+09	9.32E+09
Counts/Month												
Direct	1.09E+12	1.01E+12	1.15E+12	1.17E+12	1.20E+12	1.23E+12	1.26E+12	1.26E+12	1.17E+12	1.15E+12	1.12E+12	1.09E+12

Half of total acreage from I. Pasture used for Beef Cattle Calculations (Beef Cattle do not occupy the Hay land use).

Table C-9. Monthly Fecal Coliform Loading Counts for HC-2 by Land Use

Land Use	January	February	March	April	May	June	July	August	September	October	November	December
Counts/Acre/Day												
Cropland	1.28E+08	1.28E+08	7.22E+10	1.42E+11	2.12E+11	1.28E+08	1.28E+08	1.28E+08	1.28E+08	6.04E+11	1.96E+11	1.28E+08
Farmstead	1.54E+08	1.54E+08	1.54E+08	1.54E+08	1.54E+08	1.54E+08	1.54E+08	1.54E+08	1.54E+08	1.54E+08	1.54E+08	1.54E+08
Forest	2.05E+08	2.05E+08	2.05E+08	2.05E+08	2.05E+08	2.05E+08	2.05E+08	2.05E+08	2.05E+08	2.05E+08	2.05E+08	2.05E+08
Mixed Urban	2.78E+08	2.78E+08	2.78E+08	2.78E+08	2.78E+08	2.78E+08	2.78E+08	2.78E+08	2.78E+08	2.78E+08	2.78E+08	2.78E+08
Orchard	2.05E+08	2.05E+08	2.65E+10	5.19E+10	7.74E+10	2.05E+08	2.05E+08	2.05E+08	2.05E+08	2.05E+08	2.05E+08	2.05E+08
Improved Pasture/Hay*	1.37E+10	2.80E+10	1.59E+10	2.65E+10	3.73E+10	5.19E+10	3.22E+10	5.34E+10	1.35E+11	4.20E+09	4.33E+09	4.18E+10
Unimproved Pasture	5.38E+09	5.83E+09	5.38E+09	5.54E+09	5.37E+09	5.53E+09	5.36E+09	5.36E+09	5.54E+09	5.38E+09	5.55E+09	5.38E+09
Counts/Month												
Direct	8.51E+11	7.94E+11	9.22E+11	9.70E+11	9.93E+11	1.04E+12	1.06E+12	1.06E+12	9.70E+11	9.22E+11	8.99E+11	8.51E+11

Half of total acreage from I. Pasture used for Beef Cattle Calculations (Beef Cattle do not occupy the Hay land use).

Table C-10. Monthly Fecal Coliform Loading Counts for HC-3 by Land Use

	Counts/Acre/Day											
Land Use	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
Cropland	1.77E+08	4.86E+08	2.05E+10	3.98E+10	5.78E+10	1.77E+08	1.77E+08	1.77E+08	1.77E+08	3.09E+10	9.13E+10	1.77E+08
Farmstead	2.33E+08	2.33E+08	2.33E+08	2.33E+08	2.33E+08	2.33E+08	2.33E+08	2.33E+08	2.33E+08	2.33E+08	2.33E+08	2.33E+08
Forest	3.15E+08	3.15E+08	3.15E+08	3.15E+08	3.15E+08	3.15E+08	3.15E+08	3.15E+08	3.15E+08	3.15E+08	3.15E+08	3.15E+08
Mixed Urban	3.90E+08	3.90E+08	3.90E+08	3.90E+08	3.90E+08	3.90E+08	3.90E+08	3.90E+08	3.90E+08	3.90E+08	3.90E+08	3.90E+08
Orchard	3.14E+08	3.14E+08	8.20E+09	1.58E+10	2.35E+10	3.14E+08	3.14E+08	3.14E+08	3.14E+08	3.14E+08	3.14E+08	3.14E+08
Improved Pasture/Hay*	6.01E+09	9.46E+09	1.03E+10	1.66E+10	2.28E+10	1.47E+10	1.01E+10	1.49E+10	3.33E+10	3.87E+09	3.99E+09	1.23E+10
Unimproved Pasture	8.92E+09	9.65E+09	8.91E+09	9.38E+09	9.23E+09	9.50E+09	9.22E+09	9.22E+09	9.51E+09	9.24E+09	9.39E+09	8.92E+09
	Counts/Month											
Direct	1.93E+12	1.80E+12	2.11E+12	2.24E+12	2.30E+12	2.43E+12	2.48E+12	2.48E+12	2.24E+12	2.11E+12	2.06E+12	1.93E+12

Half of total acreage from I. Pasture used for Beef Cattle Calculations (Beef Cattle do not occupy the Hay land use).

Table C-11. Monthly Fecal Coliform Loading Counts for HC-4 by Land Use

	Counts/Acre/Day											
Land Use	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
Cropland	1.79E+08	1.79E+08	7.35E+10	1.44E+11	2.15E+11	1.79E+08	1.79E+08	1.79E+08	1.79E+08	2.52E+11	8.17E+10	1.79E+08
Farmstead	2.49E+08	2.49E+08	2.49E+08	2.49E+08	2.49E+08	2.49E+08	2.49E+08	2.49E+08	2.49E+08	2.49E+08	2.49E+08	2.49E+08
Forest	3.22E+08	3.22E+08	3.22E+08	3.22E+08	3.22E+08	3.22E+08	3.22E+08	3.22E+08	3.22E+08	3.22E+08	3.22E+08	3.22E+08
Mixed Urban	2.06E+08	2.06E+08	2.06E+08	2.06E+08	2.06E+08	2.06E+08	2.06E+08	2.06E+08	2.06E+08	2.06E+08	2.06E+08	2.06E+08
Orchard	3.22E+08	3.22E+08	1.86E+10	3.62E+10	5.38E+10	3.22E+08	3.22E+08	3.22E+08	3.22E+08	3.22E+08	3.22E+08	3.22E+08
Improved Pasture/Hay*	7.14E+09	1.60E+10	1.15E+10	2.14E+10	3.14E+10	3.12E+10	1.88E+10	3.22E+10	8.36E+10	1.15E+09	1.18E+09	2.49E+10
Unimproved Pasture	1.14E+10	1.23E+10	1.13E+10	1.17E+10	1.13E+10	1.17E+10	1.13E+10	1.13E+10	1.17E+10	1.13E+10	1.17E+10	1.14E+10
	Counts/Month											
Direct	2.36E+12	2.19E+12	2.45E+12	2.47E+12	2.54E+12	2.56E+12	2.63E+12	2.63E+12	2.47E+12	2.45E+12	2.38E+12	2.36E+12

Half of total acreage from I. Pasture used for Beef Cattle Calculations (Beef Cattle do not occupy the Hay land us